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QUANTITY AND QUALITY PARAMETERS FOR A CLEAN FLAX FIBER PROCESSING PLANT IN SASKATCHEWAN

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Flax Fibers for Cottonizing and Absorbency Products: Prospects and Problems

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Flax Fibers for Cottonizing and Absorbency Products: Prospects and Problems

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Abstract

The objectives of this study were to investigate the potential market for flax fibers in personal absorbent hygiene products and as cottonized flax in textiles; to describe quality and quantity parameters that would have to be met and the value added and job creation potential of flax fiber processing plants that target the above markets. This study found that personal absorbent hygiene products are not a good potential market for flax fiber at this time. The long term added value and job creation potential for cottonized flax looks very promising given new cottonizing technologies that are evolving and Saskatchewan could become a large volume, relatively low cost producer of cottonized flax provided sufficient funds for R&D and processing plant investments are forthcoming. Technology is evolving too rapidly to define minimum quality and plant sizes at this time.

Executive Summary

The people of Saskatchewan are continuously searching for ways to add value to Saskatchewan's raw agricultural production to help raise net incomes in rural areas. This study looked at the market potential of using clean flax fibers in the production of:

1) personal absorbent hygiene products (PAHP) such as disposable diapers; and

2) cottonized flax for use in textiles.

Unfortunately the PAHP sector is characterized, for the most part, by a few dominant companies with huge facilities that can make up to 400 diapers a minute. The plants operate around the clock and work on the principle of high volumes and low unit margins. To do this they must rely on a supply of highly consistent, readily available wood pulp fluff from pulp mills to make up the fiber absorbent core of their products. The present world flax fiber industry is neither large enough, low cost enough, stable enough or sophisticated enough at this time to supply fiber to this market. Flax fibers do, however, appear to have a number of characteristics that may provide technical and/or cost advantages to manufacturers of PAHP. These possibilities should be investigated further so that flax fibers can be used in PAHP once the flax fiber industry has overcome some of the commercial hurdles mentioned above that have stopped its use, to date, in PAHP.

The existing market for cottonized flax is very much a market for a niche or novelty fiber. This is not because the intrinsic properties of cottonized flax are poor; rather it is because the price is relatively high, the price fluctuates too much, physical properties are too inconsistent, and supply is very limited.

Almost all cottonized flax is presently produced using mechanical systems which are relatively inefficient at splitting naturally occurring flax fiber bundles into fibers which are similar to cotton in length and width; this makes it expensive to produce large lots of cottonized flax that have length and width properties consistent with cotton. Quite rapid advances are now being made in alternate methods to cottonize flax. These include the use of enzymes, steam explosion and ultra-sound. Costs of these technologies are being significantly reduced and, by their very nature, they have the potential to produce cottonized flax fibers which are cheaper and will have much more consistent fiber length and width dimensions than mechanical cottonizing.

In Chapter 2 and 3 we estimated that the demand for cottonized flax could easily double or triple from its present volume of 40-100,000 tonnes if the price were not more than 25% higher than the price of cotton and that volume demanded could easily be one or two million tonnes if the price of cottonized flax were 50%

of the price of cotton. After making allowances for marketing and selling margins at different volume levels, this worked out to a target price of US$1,330 and US$660 respectively. We then calculated the amount that could be spent on processing and on raw materials (i.e., clean flax tow) under different cost scenarios so that the total cost of cottonized flax is equal to either US$1,330 or US$660. These calculations gave us a range of clean tow prices that "new technology cottonizers" could afford to pay. Several very conservative estimates of tow cleaning costs were then made and used to calculate the cost of producing clean flax tow under different scenarios of straw collection costs, fiber contents, farmer straw incentive payments and tow cleaning costs. These scenarios showed that there were many cost combinations that would allow a non-mechanical cottonizer to produce cottonized fiber for the target cost of US$1,330 and still pay an attractive price for clean tow. There were also cost combinations that would allow a non-mechanical cottonizer to meet the price target of US$660 but the number of possibilities were naturally much more limited than at higher prices.

Following this, we estimated the range of seed and straw yields that would be typically produced in Saskatchewan if either oilseed flax or fiber flax varieties were grown. We then compared the farmer gross margins that would be obtained with different combinations of prices for seed and straw and how this would impact on the cost of fiber to a clean tow processor. The results basically showed that for lower value end-uses where quality requirements are not very high or "tight" the cheapest and/or least risky combinations would generally involving salvaging oilseed flax. However for higher value end users where quality and consistency of properties are more important, the desired quantity and quality of desired fiber attributes may not be forthcoming unless a significant straw incentive is paid. Such incentives are only cost effective if the fiber content of the straw is high and this is likely to only happen if fiber varieties or "dual purpose" varieties are grown.

When we compared these farm production scenarios with the clean tow scenarios we were able to show that both oilseed and fiber flax varieties (depending on what quality is needed) have the possibility of producing fiber at a cost low enough to permit clean tow to be produced within the target selling range and yet give farmers gross margins that would often be better than from growing alternative crops.

Thus, in theory, Saskatchewan does have the physical and cost structure potential to become a major producer of cottonized flax within the next ten years if we dedicate R&D and investment dollars to capture this opportunity.

Estimates of exports, value added and job creation potential from producing cottonized flax from 100,000 acres in Saskatchewan were made and are shown in Table 6.3.1. Although one can argue about the accuracy of individual numbers in the table, one cannot argue with the general conclusions that are shown and that is that, in the long run, there are significant export, added value and job creation

opportunities to be had by using newly developing technologies to produce and cottonize flax fiber within the province.

Table 6.3.1 - Exports; value added and job creation potential from producing cottonized flax from 100,000 acres in Saskatchewan /a

	Oilseed Flax (Straw Burnt)	**Oilseed Flax (Straw Salvaged)**	**Fiber Flax (use straw and seed)**
Seed Produced (tonnes)	62,500	62,500	25,000
Export Selling Price of Seed ($/tonne)	340	340	340
Gross Export Value ($'000)	21,250	21,250	8,500
Cottonized Flax Produced (tonnes) /b	-	7,000	68,000
Export Selling Price of Cottonized Flax ($/tonne)	-	1,900	1,900
Gross Export Value ($'000)	-	13,300	129,200
Seed & Fiber Export Value ($'000)	21,250	34,550	137,700
Farm Variable Costs ($'000) /c	10,000	10,000	20,000
Value Added After Deducting Farm Variable Costs ($'000)	11,250	24,550	117,700
Jobs Created /d	5	26	206

NOTE: All values are rough approximates made to simplify presentation of this table.
a/ 100,000 acres was chosen because it is a round number and the amount of cottonized flax produced from this area would be well below the projected quantities that would be demanded at the high cottonized flax target cost price of US$1,330 (i.e., C$1,900).
b/ Assume 100 kg/acre and 850kg/acre of clean tow respectively from oilseed and fiber flax. Assume that cottonized yield is 70% from oilseed flax tow and 80% from fiber flax tow.
c/ For oilseed flax assume $100/acre and for fiber flax $200/acre.
d/ Assume 100,000 or 62,500 tonnes of oilseed flax creates five jobs and every 1,000 tonnes of fiber cleaned and cottonized would created an additional three jobs.

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1 Introduction

Background to Study

Saskatchewan has become the largest exporter in the world of flax seed for crushing and in the last decade the provincial acreage of this crop has ranged from 500,000 to 1,000,000 acres annually. In the future this acreage may double or triple if solin (i.e., edible oil) types of flax become more popular. Aside from the seed, flax plants produce strong and relatively long fibers within their stems. In many other parts of the world flax has a long history of being grown mainly for the fiber in its stems (i.e., fiber flax) but in Western Canada we have developed flax varieties (i.e., linseed flax) which have relatively more seed and less fiber.

Although there is a lower percentage of fiber in linseed varieties, there is still sufficient fiber in the stems to make it difficult to incorporate the residual straw into the soil without having straw and fibers wrapping around tillage equipment. As a consequence, a large portion of the residual straw is burnt after the seeds are harvested. Much of the flax straw that is not burnt is collected and processed to produce fibers that can be used for specialty paper making and a substitute for glass fibers in plastic composites. Obviously such end uses are much more desirable than burning and represent a way to create jobs and add value in rural areas. It is thus beneficial to keep looking at potential new markets that could be developed for fibers from flax. Such fibers could not only come from residual linseed flax straw but also from fiber flax varieties, should market prices and quantities justify such an expansion of fiber supply.

Recent research in Saskatchewan carried out by Biolin Research Inc. has shown that by modification of traditional flax growing systems, it is possible to ret flax under Saskatchewan conditions and also that it is possible to produce clean, finely divided flax fiber that may be suitable for:

1) processing (i.e., cottonizing) into cotton like fiber that could be blended with cotton, viscose or polyester to produce garments with improved comfort and feel; and

2) use in higher-end non-woven products like tampons and disposable diapers.

Flax fibers are known to absorb 50% more moisture than cotton or wood fibers. This means that when they are blended with cotton, viscose or polyester in a garment, they will improve the comfort and feel of the garment and reduce the amount of water and sweat marking. In the case of absorbency products, flax fibers not only absorb more moisture; they are also stiffer than wood or cotton fibers. Both of these properties, in turn, can allow manufacturers to make products like tampons and disposable diapers thinner and lighter and thus more desirable in consumer's eyes.

This market study was funded by the Agricultural Development Fund of Saskatchewan to look more closely at the potential that might exist to use flax fibers in these two product categories. This will include a description of the North American, European and Asian textile sub-sectors that are or potentially may use cottonized flax to produce linen blended yarns, fabrics and garments and those that use cotton and wood based fibers to produce higher-end non-woven products like tampons and disposable diapers. It will also include background on the technical aspects of these fibers and details on historic and current volume and value figures as well as likely future trends. In addition, a technical assessment will be carried out by visiting and/or interviewing a variety of brokers, spinners, manufacturers and retailers to find out what types of fiber they are buying and why, what machinery they are using, the minimum shipment quantities that would be accepted and any other factors which may affect the potential acceptability of using clean, medium length (i.e., 2.5-10.0 cm) flax fiber in blended fiber yarns and in higher end non-wovens.

In addition, this study will present several costing scenarios of possible production, processing and marketing systems for clean, medium length flax fiber to determine in each member in a potential marketing chain (e.g., end users, manufacturers, brokers, processors, farmers) would be financially better off producing, trading or using clean, medium length flax fiber instead of what they are doing or using presently.

Given the previously mentioned information, this study will project, under various ranges of price, cost and technical parameters, the market volumes and added-value potential that might exist for the production of clean, medium length flax fiber for cottonizing and higher-end disposable products.

In summary, this study will:

(i) update and ADF funded study done in 1995 that looked at the potential size and value of the world market for cottonized flax fiber in woven and knitted textiles;

(ii) investigate the potential size and value of the world market for medium length, clean flax fiber in higher-end, non-woven products (e.g., personal hygiene products);

(iii) describe the quality and minimum quantity parameters that would have to be met if a processing plant in Saskatchewan were to target the above mentioned markets.

(iv) estimate the employment and added-value potential that might exist to produce clean, fine, medium length flax fiber for the above mentioned markets; and

2 Demand

2.1 Existing and Potential Users

Cottonized flax refers to flax fibers which have length and width dimensions that are approximately equal to the length and width dimensions of cotton. Cottonized flax is sold in a range of prices and qualities and the higher the percentage of cottonized flax fibers in a shipment that have the same dimensions as cotton, the higher the quality, the higher the selling price and the more costly it is to make. The process of turning flax fibers into cottonized fibers is called cottonization. At the present time, almost all cottonized flax is made by taking clean, well retted relatively expensive flax fiber and passing it through a series of mechanical operations to further divide and shorten the fibers until they resemble cotton fibers.

Users of cottonized flax can be found throughout the world, however, most of the spinners using cottonized flax are niche or specialty spinners that produce relatively small quantities of yarn in a year. Cottonized flax takes more care and attention to spin than cotton or synthetic fibers and hence tends to be used more by spinners who have lower labor costs and somewhat older labor intensive spinning systems (e.g., ring spinners in China) that can more easily cope with less than perfect fiber. This is especially the case where the content of cottonized flax in the yarn is high (e.g., greater than 40%). In this regard, spinners in developing countries (e.g., China, Turkey, India) are using an increasing share of total world cottonized flax production while spinners in developed countries (e.g., France, USA, Japan) are becoming a shrinking share of end-users. This is not only happening to cottonized flax, it is a trend happening with all natural fibers. Such fibers are, relative to synthetic fibers, irregular and inconsistent in properties. As labor prices rise in developed countries, spinners in such countries are pushed to using increasingly automated and sophisticated machinery to replace labor. However, such machinery does not work at high efficiency unless the raw fibers are very consistent in their properties. This means that synthetics become the fiber of choice, and often of necessity, in highly automated spinning mills. Well graded, consistent American cotton become the fiber of second choice. Other natural fibers drop out of the picture because they are not graded as consistently as cotton and hence reduce efficiencies in highly automated systems. This, in turn, creates an opportunity for spinners in low labor cost countries to specialize in natural fiber spinning. These, in turn, are often also made into fabrics and cut and sewn into garments in the same or other developing countries and exported to retailers in developed countries. Thus consumers in developed countries are increasingly wearing natural fiber garments which are imported. Thus the market for cottonized flax is shifting to spinners in developing countries.

There is one type of spinner that is, to some extent, acting contrary to this trend and that is the spinner of novelty or niche yarns. Such yarns generally only contain a small percentage of cottonized flax (e.g., 5-20%) and use cottonized flax to give their yarn a "slobby", homespun, rustic look (often popular is upholstery and drapery fabrics) or to enable them to say on the label that their fabric contains the "linen" and hence deserves to be sold at a higher price. When cottonized flax is used at such a low percentage, it causes relatively few problems in the spinning room because "the good fiber" (e.g., cotton or viscose) can easily "carry" the cottonized fiber through the spinning process. Novelty fibers are usually produced in small lots to satisfy a "just in time" need for an order of specialty fabric. Such fabric orders are usually relatively small and difficult and time consuming to source from the large spinners overseas that tend to be the exporters. The physical inconvenience of sourcing from overseas spinners combined with the fact that novelty fibers are generally more expensive than "commodity fabrics" have kept a profitable niche open for spinners in developed countries with high labor costs. This has, in turn, kept some cottonized flax of relatively low quality flowing to spinners in developed countries.

There are no exact figures on the amount of cottonized flax consumed in the world. We can only rely on estimates made by people within the industry. The lack of statistics on cottonized flax is due to several reasons:

1) no government agency compels firms to release information on how much cottonized flax they produce or consume;

2) private companies generally do not release such numbers for strategic or marketing reasons;

3) cottonizing is increasingly done by partially vertically integrated firms that cottonize flax within the same facilities that they use to produce tow and/or in the same facilities that they spin and blend yarns but they may not call themselves "cottonizers"[2];

4) import and export statistics usually only list yarns, fabrics, and garments that contain a blend of yarns by the fiber which has the biggest percentage of fiber (e.g., cotton blend yarn) but they do not collect data on the percentage, by weight, of each type of fiber; and

5) Russia and China are the world's largest producers and consumers of flax fibers for textiles but data concerning their production and use of cottonized flax internally and for export is not published widely or in English.

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[2] For example, firms that comb flax slivers, produce short combed out fibers called noils. These noils can be carded to produce an end product that is very similar to cottonized fiber but they may not call it "cottonizing"

A rough estimate would be that, at the present time, actual cottonized flax production could be as low as 25,000 Mt and as high as 50-60,000 Mt[2]. The low number assumes most cottonizing is being done in Western Europe, Taiwan and China. The higher number assumes that significantly more cottonizing is being done in China, Russia, Eastern Europe and other countries.

Reasons for Use

There are several reasons why cottonized flax is used at the present time. The first reason that makes cottonized flax attractive to many spinners is that cottonized flax can be spun on the "cotton system"; a spinning system that over 90% of the world's spinners use. This means that they do not need to buy any specialized equipment; yet they can incorporate a non-traditional fiber that is neither cotton nor a synthetic (i.e., unlike "long line" or "tow" flax fibers which must be spun on "the linen or wool" systems which are no longer common in most textile mills). The second is that the incorporation of a small percentage (e.g., less than 20%) of cottonized flax into a blend of cotton, viscose or polyester will give the yarn a rustic or homespun "linen" look and such a look seems to be in fashion every four or five years. The third reason is that the addition of small amounts of flax allow yarn, fabric, and garment makers to put linen on the label which lists the fiber composition. This may allow them to charge a significantly higher price for their product since it has some "noble linen fiber" in it.

A fourth reason for incorporating cottonized flax into a garment is that if the percent of cottonized flax in a blend is more than 50%, that product becomes a "linen-blend" product and not a cotton or viscose or polyester blend. In the case of the NAFTA countries, this is important to major textile exporting nations like China because the NAFTA countries have a quota or "cap" on total amount of cotton, viscose and polyester blend clothing that can be imported. Once the quota is met, an exporter of such blended articles can only export to the NAFTA countries if quota is purchased from an existing exporter. However, in NAFTA countries there is no quota for linen or silk-blended products; thus it is common for China which has access to internally produced cottonized flax, to export a large amount of 55:45 linen:cotton blend garments to NAFTA countries. This allows China to increase foreign exchange earnings and domestic jobs, uses up flax tow produced during traditional long line flax production and avoids problems with quotas in NAFTA countries.

A fifth reason to use cottonized flax is because, for the same weight of fiber, cottonized flax can absorb 50% more moisture than cotton before feeling wet. It is also stronger and more durable and can be washed more often before it shows the same degree of wear as a fabric containing the same percentage of cotton. Thus a golf shirt made with a blend of cottonized flax and polyester would feel much cooler and would show less perspiration stains than a blended cotton and polyester golf shirt; a towel made from cotton and cottonized flax would take longer to feel damp and would have a longer useful life than a pure cotton towel. These examples show applications in which the use of cottonized flax would produce a product that would be superior to those presently being made.

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[2] Capacity, including that of "rough" cottonizers in China, could be 90,000-100,000 tonnes annually.

In addition to the above reasons that make blends using cottonized flax fiber desirable from a consumer's point of view, there are several other reasons why spinners, weavers and garment makers, (especially the smaller ones) might be persuaded to incorporate cottonized flax into their lines. First of all, these processors want to continually come up with a new product that will help them differentiate their products from that of their competitors. Blends containing flax fibers are still uncommon at present and hence offer new ways to diversify a company's products. Second, incurring a relatively small additional cost to introduce a blend containing a new and superior fiber would allow processors to sell that blend for a relatively large additional amount. Introducing a relatively high percentage of cottonized flax into a shirt may increase the cost by 30% due to higher material costs and lower spinning and weaving efficiencies but such shirts often can be sold for 100% more because of the higher linen content (this is similar to the car company that is able to sell a "fully loaded" car for, say, $3,000 more than a standard car, even though the cost of "fully loading" it may only be $600). Because of this, some spinners and weavers have been willing and able to pay more (i.e., roughly double for higher end quality) for cottonized flax than for cotton.

In theory garment makers can sell garments containing significant levels of cottonized flax for a price that more than compensates them for their extra expenses, but the price premium they are able to obtain will be very much a function of how potential consumers view the extra satisfaction and enjoyment they will get from wearing a garment containing cottonized flax. This, in turn, depends to a large degree on the amount of advertising, promotion and information that the potential consumer is exposed to, in regard to the merits of cottonized flax relative to other fibers. Who will pay for such promotion? If one firm (e.g., Calvin Klein) or one retail chain (e.g., The Gap) were to promote cottonized flax; other firms and chains could spend nothing on promotion but still enjoy higher sales of cottonized flax products. This "free rider" problem discourages individual firms and chains from promoting a particular fiber.

The cotton and wool industries got around this problem by forming commodity oriented bodies (e.g., Cotton Inc. in the USA) which receive check-off funds from all farmers and cotton processors to use for generic promotion of their particular fiber (e.g., the "cotton - the fiber of our lives" advertising campaign). This approach avoids the free rider problem yet has been shown to increase the demand for items containing the promoted fiber (e.g., cotton). This approach might also work for cottonized flax but, at the moment, there is a void. Existing flax oriented groups and companies in Western Europe (e.g., those using the stylized "L" which represents European sourced linen) are carrying out only very limited promotional activities for pure linen and almost nothing for cottonized flax. In North America, to date, flax oriented groups have only been interested in promoting the seed from flax.

Many existing spinners who operate the "cotton system" feel that:

1) the price of cottonized flax is often too high;
2) the price fluctuates too much relative to other fibers;
3) the quality traits are not consistent enough; and
4) that the quantities offered are not large enough for large scale factories to justify starting a new product line.

Most of the cottonized flax that is now consumed is spun by smaller operators who are selling into higher priced niche markets. These smaller operators are willing and able to shift between fibers and blending combinations because their buyers tend to order smaller and higher priced job lots than do the huge mass market buyers who buy from the very large scale spinners, weavers and garment makers. However, many big spinners would be very interested in buying large quantities of cottonized flax if a supplier could guarantee large quantities of consistent quality at somewhat lower than cotton prices.

Over 90% of the world's spinners use the "cotton system" to spin cotton and synthetic fibers. What follows is a brief description of this system and several variations of it. For readers who have not visited a spinning mill or seen a video about a spinning mill; verbal descriptions of the cotton system are challenging to understand. In such cases the reader should at least come away with the realization that, for wide spread acceptance, cottonized flax must have quite specific parameters to allow it to be used easily on existing equipment.

2.2 Technical Considerations

2.2.1 The Cotton System

Ring spinning The basic cotton system is centered around the ring spinning process. While a variety of other methods for preparing cotton yarns are in use, the ring process remains the most widely used and the process best adapted to preparing yarns of varied sizes.

Most mills use some types of automated system in the manufacture of yarns. This automation may involve all the steps from opening the fiber bale to the final yarn spinning, or segments of the process may be automated. The general steps in ring spinning are cited in the following paragraphs, with automated processes indicated where appropriate.

Cotton cleaning, blending and opening Cotton and/or other staple fibers of similar length arrive at the processing unit or mill in a large bale. Each bale has normally been graded and/or has had certain properties tested by cotton dealers or government appointed agencies. Fiber samples from bales may or may not be re-tested by the spinner before use. To make cotton yarns, or yarns blended of two or more different types, it is important to mix fibers so that the resulting yarns will be of uniform quality. The first step, therefore, is to combine fibers from several different bales and sources. Once the bales are opened, thin layers of fibers from several bales are fed into the blending machines. These machines loosen and separate the closely packed fibers and remove dirt and other heavy impurities present, either by gravity or by centrifugal force, thereby ensuring that fibers are well blended into a uniform mix. The opened bales of fiber are set into position, and metal fingers pull fibers from the base of the bale. These fibers are then blown to separate and fluff them and are next fed directly into the carding unit.

Picking The intermittent ring spinning system requires that the fibers from the opening units be transported to the picker frame in some compact form or on some type of conveyor system. The picker frame does additional cleaning of the fibers and then forms them into a rolled mat that is ready for setting in place on the card frame. This roll of fibers is called a lap; it is about forty-five inches wide and of randomly oriented or arranged fibers that resemble absorbent cotton in form and shape. Quality of the yarn is dependent to a considerable degree upon the thoroughness of the picking operation and the uniformity of the picker lap.

Carding In the intermittent process the picker lap is transported and placed at the end of the carding frame. In the automated system, fibers are fed directly to the carding frame by either air systems or a combination of air and gravity. Carding continues the cleaning process, removing fibers too short for yarns and separating and partially straightening the fibers so that their longitudinal axis are somewhat parallel. These fibers are then spread into a thin, uniform web. The web moves into a tunnel-shaped device where it is gathered into a soft mass and formed into the card sliver. This sliver is a ropelike strand of fibers about three quarters inch to one inch diameter. The card sliver is not completely uniform in diameter, and the fibers are considerably more random in arrangement than a combed sliver. Carded yarns go directly to the drawing machine; combed yarns receive additional processing before drawing.

Combing For high-quality yarns of outstanding evenness, smoothness, fineness, and strength, the fibers are combed as well as carded. In the combing operation several card slivers are combined and then drawn onto the comb machine where they are, once again, spread into a web. As the web is formed there is further cleaning and straightening of the fibers. Short fibers are removed during combing. After the combing, the fibers are pulled from the combing wires and formed into a combed sliver. This sliver will produce yarns of high quality.

Drawing Depending on the quality of yarn desired, drawing follows either carding or combing. Several slivers are combined and conveyed to the drawing machine, where they are pulled together and drawn out into a new sliver no larger than one of the original slivers. If the yarn is to be an intimate blend of two or more fibers, the slivers will be composed of different fibers. For example, one sliver of cotton fiber for each sliver of polyester fibers will produce a blend of approximately 50 percent polyester and 50 percent cotton. Drawing does not insert any twist into the drawn sliver.

Roving The sliver from the drawing frame is taken to the roving frame where it is attenuated until it measures from one quarter to one eighth of its original diameter. As the roving strand is ready to leave the roving frame, a slight amount of twist is imparted to hold fibers together. The sliver is then moved to the spinning frame. The fineness of the final yarn depends, to some degree, on the number of times the slivers are doubled and redrawn prior to the roving operation.

Spinning The final process in the manufacture of spun yarns is the actual spinning operation. In the spinning frame the roving is further stretched and drawn to the ultimate diameter of the final yarn. During this operation, twist is inserted. Several methods are used for inserting twist into the final yarn, but the most common for fibers the length of cotton is the ring-spinning system. In ring spinning, the drawn-out roving is guided in a downward direction and through the traveler, a small inverted U-shaped device. The spindle upon which the completed yarn is wound rotates approximately 13,000 revolutions per minute; the traveler moves around the ring at a rate between 4,000 and 12,000 revolutions per minute. As the spindle revolves to wind the yarn, the yarn passes through the traveler, which carries it around on the ring. This process imparts the desired amount of twist. The yarn formed on the spinning frame is called a single yarn.

Variations of the Cotton System

There have been many developments in yarn manufacturing since the 1960s. These newer processes are important for the manufacture of selected types and counts of yarn, and open-end spinning has become particularly popular for coarser yarns and/or in developed countries where wages in spinning mills are relatively high.

Open-end spinning

Often also called rotor spinning, break spinning, or element spinning, this involves the processing of fibers direct from a fiber supply, such as a roving sliver, to the finished yarn. Depending on the equipment, the fiber supply may be in the form of a card or combed sliver, a drawn sliver, or a roving sliver. The process eliminates separate drawing, roving, spinning and winding operations and hence have the potential to significantly reduce labor requirements and increase yarn production per hour.

Three basic open-end methods are in use: mechanical, electrostatic, and fluid or air. The mechanical process is the most common. A fiber supply, such as a card sliver, is fed by mechanical devices to the actual spinning area. This area involves the contact of fibers with devices such as funnels, cones, baskets, sieves, or needled surfaces. As the fibers arrive at the spinning area, they are separated by a current of air, gas of some type, or a liquid. The individual fibers are forced into the collecting area where they form the yarn, twist is inserted, and the completed yarn is delivered to the take-up package.

The electrostatic spinning method utilizes an electrostatic field that controls the direction of movement and the arrangement or orientation of fibers during the spinning process. The electrostatic field is achieved by creating a negative charge to the area and the rollers that feed the sliver into the spinning area and creating a positive charge in the twisting device – that portion that forms the actual yarn. As the fibers move from the negative to the positive area, they are separated, arranged into a parallel relationship, stretched or drawn, and then transferred to a mechanical twisting area where the final twist is imparted into the yarn.

The fluid or air systems are seldom used as yet, but they involve fiber movement by means of some type of liquid or air flow. Most open-end spinning at the present utilizes the mechanical systems.

Open-end yarns present both advantages and limitations. The advantages include increased speed of production, less labor required, and less floor space required for equipment – all of which are responsible for manufacturing economies. The finished yarn can be wound onto any type of package; the yarns are even in diameter and smooth in appearance, and there are fewer knots or neps. The major limitations to open-end yarns seem to be that they are not quite as strong as ring-spun yarns, and it is not possible to make extremely fine yarns. The capital cost of open-end spinning frames are 20-40% higher than ring spinning frames and hence open-end systems are not as financially attractive to use in countries where wage rates are very low.

2.2.2 Basic Principles of Yarn Construction

An important step in converting textile fibers into fabrics for use in making textile end-use products is to arrange fibers in some way. When fabrics are woven, knitted, braided, or knotted the fibers must be first put in a continuous, thin, even twisted band of fibers called a yarn. This section details the basic principles involved in making yarns.

Yarn is defined by the American Society for Testing Materials as:[3]

> *A generic term for a continuous strand of textile fibers, filaments, or material in a form suitable for knitting, weaving, or otherwise intertwined to form a textile fabric. Yarn occurs in the following forms:*
>
> *a. a number of fibers twisted together;*
>
> *b. a number of filaments laid together without twist;*
>
> *c. a number of filaments laid together with more or less twist;*
>
> *d. a single filament . . . a monofilament; or*
>
> *e. one or more strips made by the lengthwise division of a sheet of material such as a natural or synthetic polymer, a paper, or a metal foil.*
>
> *Insertion of the phrase "or strands" following "continuous strand" in the foregoing definition will serve to broaden and clarify the use of the word yarn, as it is interpreted in this text. There are different types of yarns available, and these include single yarns, plied yarns, cord yarns, simple yarns, complex or fancy yarns, and thread.*

Yarns can be made either from short, staple-length fibers or from filament fibers. If filaments are used, the yarns may be either multifilament (composed of several filaments) or monofilament (composed of a single filament). The staple fibers may derive from natural fibers that are available only in short lengths[4]; they can be formed from the natural fiber silk when filaments are cut into short lengths, or when the short ends of silk are removed from cocoons during processing; or they may be composed of any man-made fiber by the simple process of cutting filaments into short lengths. Staple fibers require considerably more processing than filament fibers to form yarns.

The art and science of converting masses of loose fibers into yarn and thread[5] spans thousands of years. Modern technology now allows fibers to be used in a multitude of non-yarn constructions (e.g., high loft, spun bond, air laid, wet laid, etc.) but the majority of fibers used in textiles are still turned into yarn before they are woven or knitted into fabrics.

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[3] American Society for Testing Materials, *Yearbook*, (Part 32, 1981), p. 78.

[4] Staple length fibers are normally thought of as being the length of cotton (i.e., three quarters to an inch and half) but also include fibers such as viscose which may be cut at two inch lengths.

[5] Yarns and threads are structurally the same; however, they have different end uses. Yarns are woven or knitted together to produce fabrics. Threads are relatively strong yarns which are used single or twisted together to sew or hold together two or more pieces of material (usually fabric).

Yarn construction is becoming ever-more complicated. Different textile market segments demand different types of yarns because the type of yarn that is used has a great influence on the properties and cost of the final product. Thus the actual and potential demand for cottonized flax is directly related to the type of yarns that can be made from cottonized flax. In the following paragraphs we present a brief introduction to some of the principles of yarn construction so that we have a better idea of how cottonized flax is being used now and what quality parameters will have to be met if it is to be used more extensively in the future.

A "fiber" has often been defined as a small piece of material in which the length is at least 100 times the width. Such extreme differences in dimension are important when fibers are twisted together to make a continuous twisted bundle of fibers called a yarn. A yarn should be continuous so that the mechanical operations of weaving or knitting can be carried out with little or no stoppage. A yarn should have a relatively fine diameter so that the resultant fabric is light weight and drapes easily around a human body or over furniture like beds and tables. If a fiber is too short, relative to its diameter, it cannot be twisted sufficiently around other similar fibers to produce a fine diameter yarn that will stay together and have strength. Yarns can sometimes be made from such short fibers but the yarn thus produced would be a thick, rough yarn (e.g., sisal fibers are thick, strong and stiff; they can only be used to produce items like baler twine and rope).

The strength of a yarn, is to a large degree, determined by:

1) the number of fibers in a cross-section of yarn;

2) the friction between the surfaces of the fibers;

3) the strength of the individual fibers;

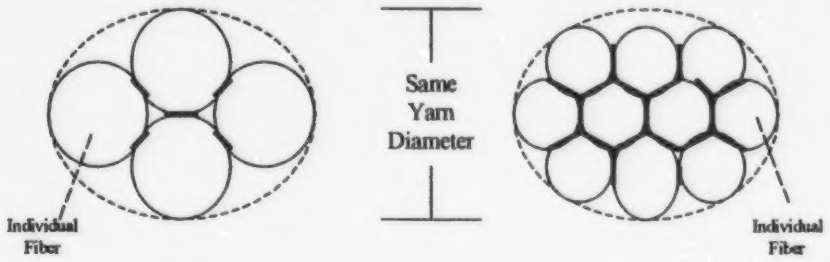
4) the number of fiber "ends" in a given length of yarn;

5) the regularity of fiber "ends"; and

6) the amount and type of twist given the yarn.

The following diagrams may assist in understanding these relationships.

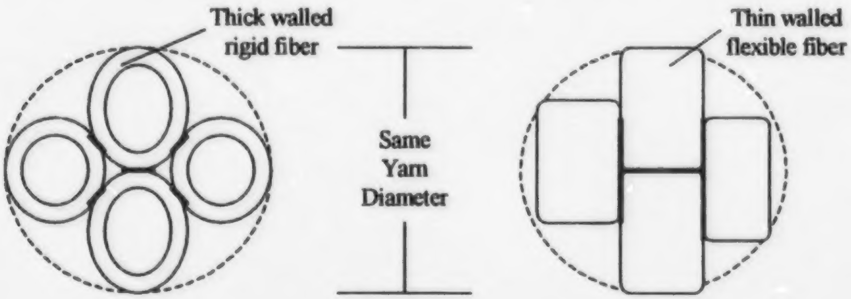
Figure A – Thick fibers **Figure B – Thin fibers**



(1) For a given diameter of yarn, the greater the number of fibers, the stronger the yarn. Figures A and B represent the end views of yarns of similar diameter; however, the fibers making up the yarn in Figure A are much finer (small diameter) than those making up the yarn in Figure B. The darkened lines indicate points of contact and create friction between the fibers. There are many more points of contact and hence, friction, between the fibers in Figure B and hence the yarn in Figure B will be much stronger than the yarn in Figure A, even if the individual fibers in Figure B are weaker because each fiber in B has a smaller diameter.

(2) For a given diameter of yarn, the more friction between the surfaces of fibers in a yarn, the stronger the yarn.

Figure C – Stiff fibers **Figure D – Flexible fibers**



Figures C and D represent the end views of yarns of similar diameter with similar numbers of fibers in the cross-section (i.e., four), however, the yarn in Figure C is made up of thick walled rigid fibers (e.g., flax fiber), while the yarn in Figure D is made up of thin walled flexible fibers (e.g., cotton)[6]. The darkened lines indicate points of contact and hence friction between the fibers. Since there is much more friction indicated in Figure D relative to Figure C, the yarn shown in Figure D will be stronger than the yarn shown by Figure C. Alternatively, if we needed to make a yarn of a given strength, we could produce a thinner diameter yarn with the thin walled flexible fibers shown in Figure D relative to the thicker diameter yarn we would need to produce if we used the thick walled rigid fibers of Figure C.

(3) For a given diameter of yarn and a given number of cross-sections, the stronger the fiber, the stronger the yarn.

Figure E – Weak fibers **Figure F – Strong fibers**

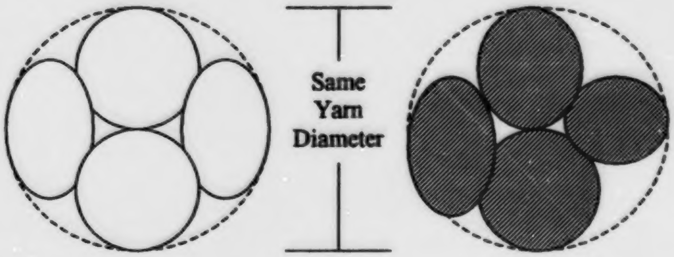


Figure E and Figure F represent the end views of yarns of similar diameter, similar cross-sections and similar friction co-efficients, but the fibers making up the yarn in Figure F are made up of a stronger material (e.g., kevlar) than the fibers (e.g., polyester) used in Figure E. In such a case, the yarn in Figure F will be stronger than the yarn shown in Figure E.

(4) For a given diameter of yarn with a given number of fiber cross-sections, the greater the number of fiber ends in a given length of yarn, the weaker the yarn.

---

[6] In actual fact, cotton fibers are not square like these shown in this stylized drawing and flax fibers are not perfectly round. Cotton fibers do, however, have thinner walls than flax and hence cotton can be squeezed together more easily in a yarn than flax.

Figure G – Short fibers

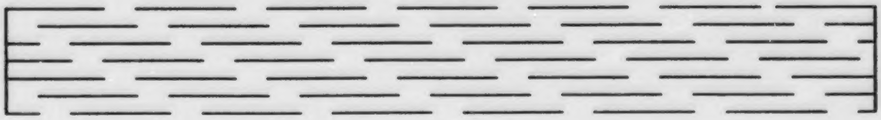
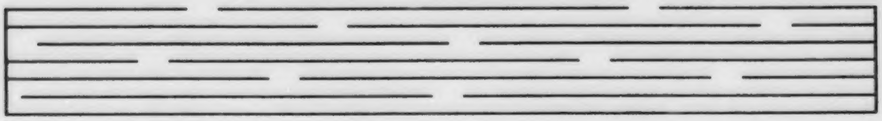


Figure H – Long fibers



Figures G and H represent the top view of yarns of similar diameter and similar number of fibers in their cross-section, however, the yarn in Figure G is made up of many short fibers (and hence many fiber "ends") while the yarn in Figure H is made up of fewer long fibers (and hence fewer fiber "ends"). In such a situation, the yarn in Figure H will be stronger than in Figure G or, conversely, we could spin a finer (i.e., thinner) yarn with Figure H fibers than with Figure G fibers (e.g., finer yarn can be made from extra length Pima cotton than from normal upland cotton)

(5) For a given diameter of yarn with a given number of cross-sections, the more irregular the pattern of fiber "ends", the weaker the yarn.

Figure J – Irregular fiber ends

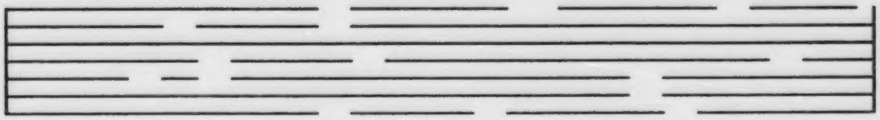
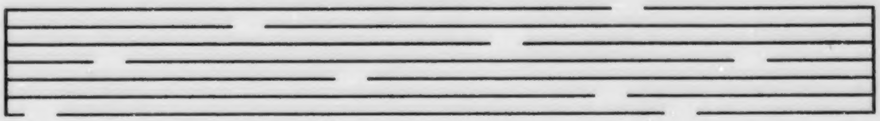


Figure K – Regular fiber ends



Figures J and K represent the top view of yarns of similar diameter and similar numbers of fibers in their cross-section. However, the yarn in Figure J is made up of fibers of many different lengths and hence there are many points in the yarn where fiber "ends" line up with each other and create a weak point in the yarn (i.e., if four out of five fibers end at the same point, the yarn is only as strong as the remaining one fiber, even though the yarn is five fibers thick). Figure K is made up of fibers of even lengths and shows an even distribution of fiber ends within the yarn – In this example not more than two out of five fibers end at the same point and hence, the yarn is always as strong as the interactive strength of three fibers. Hence the yarn represented in Figure K would be much stronger than the yarn represented by Figure J. Repeated drafting and using fibers with very consistent fiber lengths will help produce fibers like those shown in Figure K.

The relationship between fiber length distribution and yarn strength is a very important one since it has a very significant impact on the fineness (i.e., thinness) of the yarn that can be produced, the speed at which spinning and weaving can be carried out, the effective yield of yarn and hence the cost of the yarn. Fiber length distribution is so important that it is one of the main characteristics that spinners want to know before they purchase fibers.

Figure M – Poor length distribution

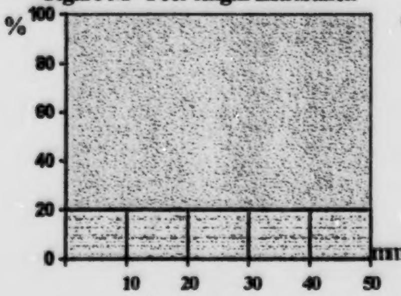


Figure N – Good length distribution

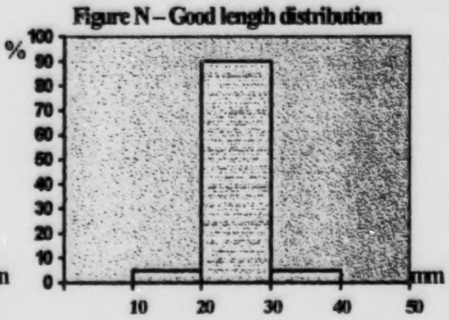


Figure M and Figure N represent two extreme distribution patterns of fiber lengths. In Figure M 20% of fibers are from 0-10 mm in length, 20% are from 10-20mm, 20% are from 30-40mm, and 20% are 40-50mm. A spinner would have extreme difficulty using such fiber to make a yarn. On the other hand, 100% of the fibers in Figure N are 30-40mm. These would be easy for a spinner to use to make strong yarn because he could be quite confident that the fiber ends will be distributed evenly enough throughout the yarn. In addition, a spinner would have little wastage after setting his spinning frame for this type of fiber and he could increase his spinning speed (i.e., throughput per hour) because he would have a greater assurance that there would be few yarn breaks.

Fiber distributions are often shown in a cumulative manner rather than in the distribution shown in Figures M and N. Examples of such cumulative distributions are shown in Figures P and Q, this is an alternative way to illustrate the information shown in Figures M and N.

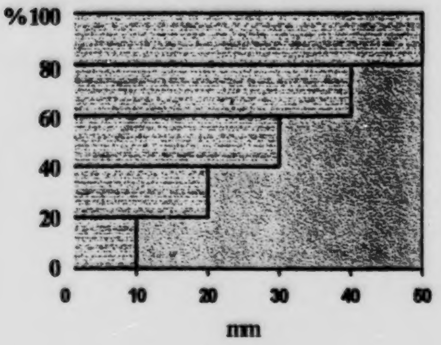


Figure P – Poor cumulative distribution

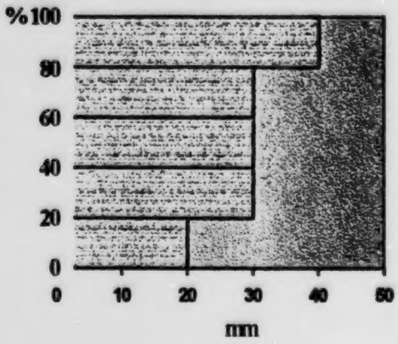


Figure Q – Good cumulative distribution

Figure P shows that 20% of the fiber is 10mm or less in length, 40% is 20mm or less, 60% is 30mm or less and so on. We could also quickly calculate that 20% (80% - 60%) of the fibers are 30-40 mm in length. In Figure Q we can see that 5% fibers are less than 20mm, 90% of fibers are 20 to 30 mm and 5% are from 30 to 40mm. In essence, Figures M and P and N and Q show the same information, however, different spinners prefer different types of fiber length distribution graphs. Almost without exception, the tighter or narrower the distribution of fiber lengths, the happier the spinner will be, providing the majority of fiber lengths are within the range that can be handled by the spinning equipment that is available.

(6) For a given diameter of yarn with a given number of cross-sections; the more twist, to an optimum point, the stronger the yarn. In conventional processes used in making yarns, as the fibers are combined to form yarn, twist is inserted to help hold the fibers together. The amount of twist is sometimes identified rather broadly by such terms as low, medium, and high. It is more accurate, however, to indicate twist by the number of turns per unit length (metric or inch), the number needed to form the best possible yarn varying with the yarn diameter. As the yarn becomes finer, it requires more twist per unit length. However, it should be noted that the amount of twist also influences yarn diameter to some degree; the more twist to an optimum point, the more compact and, hence, the finer the yarn will be. Beyond an optimum point, however, added twist will cause the yarns to kink, and eventually the yarn will become brittle and lose strength. Increased twist will add elasticity to yarns. This can be observed in the stretchy and "curly" characteristics of crepe yarns, which are highly twisted. Other positive factors that occur as a result of a high amount of twist include the following: these yarns are more resistant to abrasion; they shed soil easily because of a smoother surface and less space between fibers for soil to lodge; and they tend to appear smooth,

uniform, and of low luster. Yarns with low twist are soft and fluffy; they tend to be warmer because there are air spaces to serve as insulation areas. Filament yarns of low twist have more luster as they reflect more light than high-twist yarns. Low-twist yarns tend to have more surface texture, show abrasion wear more quickly, and are less strong than yarns with high twist.

Balanced yarns are those in which the twist is such that the yarn will hang in a loop without kinking, doubling, or twisting upon itself. Unbalanced yarns have sufficient twist to set up a "torque" effect, and the yarn will untwist and retwist in the opposite direction. Smooth fabrics require balanced yarns, but for crepe and textured effects unbalanced yarns are frequently used. Crepe yarns are also produced by balanced yarns with sufficient enough twist that kinking occurs. Various effects can be obtained by combining yarns of different twist direction, and durability may be increased by efficient plying of S and Z twist single yarns.

2.2.3 Yarn Number

The textile industry has developed several systems to enable yarns to be categorized for technical and commercial reasons. The most commonly used system is that of using yarn numbers.

The yarn number is a measure of linear density. Direct yarn number is the mass-per-unit length of yarn; indirect yarn number is the length-per-unit mass of yarn. Yarn number is frequently called yarn count in the indirect system. To some extent the yarn number is an indication of diameter when yarns of the same fiber content are compared.

Over the years various methods of determining yarn number have been developed. Cotton yarns are numbered by measuring the weight in pounds of one 840-yard hank; the count is then reported as the number of 840-yard hanks required to weigh one pound. For example, if 840 yards of cotton weigh one pound, the yarn number is 1s; if it requires 30 hanks to weight one pound, the yarn number is 30s. A heavy yarn would be 1s; a medium yarn, a 30s, and a very fine yarn 160s[7]. Woolen yarn is measured by the number of 300-yard hanks per pound, whereas worsted yarn is measured by the number of 560-yard hanks per pound. The metric equivalent of the Cotton and Wool count systems shows how many kilometers of yarn are in one kilo of yarn. Silk and man-made fiber yarns are usually measured using the denier system. The denier is equal to the weight in grams of 9,000 meters of yarn.

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[7] This system is often referred to as the "English Cotton Count", "Cotton Count" or "English Count" and abbreviated as "Ne" to differentiate it from the metric or "Nm" system.

Owing to the international scope of the textile industry, a universal system for yarn numbering or yarn count has been developed. This method, called tex, determines the yarn number by measuring the weight in grams of 1 kilometer (1,000 meters) of yarn. The weight is the tex yarn number. For many years this method was supported by research groups, but it has not met with widespread commercial acceptance. During the past few years, however, the picture has changed somewhat. As nations adopt the metric (SI) system of measurements, the use of tex will increase and should eventually become the standard unit for yarn count or yarn number.

Table 2.2.1 - Yarn conversion table

English Count (Ne)	Metric Count (Nm)	Linen Count (Lea)	Tex (Tex)	Denier (Dn)
10	16.9	28.7	59.0	531.0
20	33.9	57.4	29.5	265.5
30	50.8	86.1	19.7	177.3
40	67.7	114.8	14.8	133.2
50	84.7	143.5	11.8	106.2
60	101.6	172.1	9.8	88.2
70	118.6	200.8	8.4	75.6
80	135.5	229.5	7.4	66.6
90	152.4	258.2	6.6	59.4
100	169.4	286.9	5.9	53.1
5.9	10	16.9	100.0	900.0
11.8	20	33.9	50.0	450.0
17.7	30	50.8	33.3	299.7
23.6	40	67.8	25.0	225.0
29.5	50	84.7	20.0	180.0
35.4	60	101.6	16.7	150.3
41.3	70	118.6	14.3	128.7
47.2	80	135.5	12.5	112.5
53.1	90	152.5	11.1	99.9
59.0	100	169.4	10.0	90.0

Conversion rates:
1s English count = 840 yards/lb.
Metric count (Nm) = km/kg of yarn

1 yard = 36 inches
1 meter = 39.37 inches
:. 1 yard = .9144 meters
1 kg = 2.205 lb.
:. 840 yards/lb. = 840(.9144)*2.205
= 1.694
:. (Ne) * 1.694 = (Nm)

:. (Nm) = (Ne) * 1.694

Lea = Nm * 1.694

Tex = weight in grams of 1,000 meters of yarn
(NOTE: Decitex = 1/10 of a Tex)

:. Tex = 1/Nm * 1,000

Denier is officially the number of 0.05 gram units in a 450 meter length (i.e., the weight in grams of 9,000 meters of yarn)
:. Denier = Tex * 9

2.2.4 Importance of Fiber Quality

Over 90% of the world's textiles are spun using not only the machinery of the cotton system but also the fiber quality measurements used by the cotton industry. Since the USA is the world's largest cotton exporter, the system it uses to establish the quality of cotton fibers has a great influence on the measurement parameters and systems used to measure fiber properties by cotton and synthetic fiber spinners throughout the world.

Each sector of the fiber industry receives significant benefits from the present system of measuring and reporting fiber quality. Producers use fiber property values as a check on production and harvesting methods. These values also help determine what premiums or discounts can be expected for the marketed quality, if applicable. Quality measurements permit fiber merchants to more effectively assemble bales into even-running lots (large numbers of bales of like quality) to better satisfy textile mill specifications on purchase contracts.

Quality measures are also used in forward contracts and on organized exchanges, in addition to uses in the usual producer-to-merchant-to-mill marketing chain and indirect producer-to-mill sales. Information on quality, despite its addition to marketing costs, is essential for efficient operation of all alternative marketing arrangements and helps enhance the competitiveness of all fibers using similar quality measurement systems.

For textile mills, different end-use requirements, such as yarn strength and yarn and fabric appearance, require different fiber qualities. The ability of a fabric to hold dyes, as well as recently developed finishes such as shrink resistance, flame retardence, and durable press, depends on fiber qualities. For given product requirements or spinning characteristics, a textile producer may not be able to obtain all the raw fiber qualities needed when buying a particular generic type cotton from a given location. Fiber quality of a particular cotton variety can vary widely by farmer and year. In such instances, quality measures become the basis for recipe of sorts; the textile producer blends, or lays down, mixes of various types of cotton to obtain a specific quantity of cotton with the required quality measures. Some properties, such as trash or length uniformity, spindle speed, end breakage, or losses due to waste, also affect cost of production. Staple length or fineness and maturity affect yarn and fabric quality such as appearance, strength, and fabric feel. Synthetic fiber producers, can, on the other hand, produce very regular and consistent fibers, however, they generally still report fiber quality characteristics using cotton system parameters so they are easily understood.

2.2.5 Cotton Classification in the USA

Cotton classification in this section refers to the application of standardized procedures developed by the AMS[8] that measures the physical attributes of raw cotton that affect finished product quality and/or manufacturing efficiency. AMS classification currently consists of determinations of fiber length, length uniformity, strength, fineness, color, leaf, preparation, and extraneous matter. This is generally now done using High Velocity Instrumentation (HVI) determination of the following properties.

Fiber Length

Fiber length measures the average length of the longest half of the fibers (upper-half mean length). It is reported in both 100ths and 32nds of an inch and is measured by passing a "beard" of parallel fibers through a sensing point. The beard is formed when fibers are grasped by a clamp from a sample of cotton and then combed and brushed. Combing and brushing parallels the fibers and removes the crimp.

Cotton fiber length is largely determined by variety, but it can also be influenced by weather and soil conditions. Excessive temperatures, inadequate moisture, and mineral deficiencies can cause fiber deterioration, which can result in decreased fiber length. Fiber length measurements are essential to the yarn manufacturing process, as fiber length is directly related to yarn fineness, yarn strength, and spinning efficiency.

Length Uniformity

Length uniformity is a measure of the degree of uniformity of fiber lengths (the ratio between the mean length and the upper-half mean length, expressed as a percentage). The measurements are obtained in the same manner as that for fiber length. The same beard of cotton used for measuring fiber length is used to measure length uniformity. If all of the fibers in the sample were of the same length, the mean length and the upper-half mean length would be the same and the uniformity index would be 100. However, cotton fibers within a sample vary considerably, so length uniformity will be less than 100 (
Table 2.2.2). Improper gin machinery settings, over-cleaning, and excessive drying can contribute to fiber breakage during the ginning process, which in turn results in lower length uniformity.

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[8] Agricultural Marketing Service, USDA.

Table 2.2.2 - Length uniformity description and HVI index

Description	*HVI-length uniformity index*
	Percent
Very High	> 85
High	83-85
Intermediate	80-82
Low	77-79
Very Low	<77

Source: USDA-ERS

Length uniformity is related to such yarn characteristics as spinnability, yarn uniformity, and yarn strength. It is also related to short fiber content. Cottons with a low uniformity index are likely to have a high percentage of short fibers (shorter than one-half inch). Such cottons may be difficult to process into yarn because of excessive fiber breakage in spinning.

Fiber Strength

Strength measurements are reported in terms of grams per tex (Table 2.2.3). A tex unit is equal to the weight in grams of 1,000 meters of fiber. Therefore, the strength reported is the force in grams required to break a bundle of fibers 1 tex unit in size. Strength measurements are made on the same tapered beard of cotton used for measuring fiber length. The tapered beard of cotton is moved into a 1/8-inch opening between clamping jaws where the fibers are broken. Fiber strength is largely determined by variety. However, other factors such as improper ginning, soil deficiencies, environment, and weather can affect fiber strength.

Table 2.2.3 - Fiber strength description and HVI readings

Description	HVI strength[9]
	Grams/tex[10]
Very strong	30 and above
Strong	27 – 29
Intermediate	24 – 26
Weak	21 – 23
Very weak	20 and below

Source: USDA-ERS

In processing cotton into yarn, fiber strength is especially important to the opening and cleaning process, where fibers are exposed to harsh treatment. During the subsequent process such as carding, drawing, roving, and spinning, the fibers must have adequate strength to withstand breakage due to pressures applied during drafting. Fiber strength is generally considered to be the most important fiber property for predicting the strength of rotor-spun yarn, and, with the exception of length, is the most important fiber property for predicting the strength of ring-spun yarn.

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[9] Force in grams required to break a bundle of fibers 1 tex unit in size.

[10] 1 tex unit = Weight in grams of 1,000 meters of fiber

Fineness

Fiber fineness is determined by the measurement of the air permeability of a mass of cotton fibers when compressed to a fixed volume. An airflow instrument compresses the fibers, and the measurement is commonly referred to as "micronaire" or "mike". The information is used to determine the relative size or fineness of fibers. The micronaire reading can also provide a relative indication of fiber maturity or cell wall thickness for varieties of cotton with similar fiber parameters. Fiber fineness can be influenced during the growing period by environmental conditions such as moisture, temperature, sunlight, soil fertility, and extremes in plant or boll population.

Fiber fineness affects mill processing performance and the quality of the end product in several ways. In the opening and cleaning process, cotton with low micronaire readings or fine-fiber cottons require gentler handling at slower speeds. In carding cotton with finer fibers, slower carding rates are necessary to prevent damage to the fibers. In the drawing process, the knowledge of fiber fineness and length is critical for making the proper roller settings. In the roving and ring-spinning processes, fiber fineness can influence the amount of twist needed in the roving and the yarn. In rotor-spun yarn, finer fibers or more fibers per cross-section will result in stronger yarns. Dye uptake by the fibers will vary with micronaire readings. Dye absorbency and retention are generally higher for coarser fibers, which give high micronaire readings.

Color

The color of cotton is measured by the degree of reflectance (Rd) and yellowness (+b). Reflectance indicates how light or dark a sample is, and yellowness indicates how much yellow color is in the sample. A three-digit color code is used to indicate the color grade and the particular quadrant within that color grade on a color diagram called the Nickerson-Hunter cotton colorimeter diagram. The color code is determined by locating the point at which the Rd and +b values intersect on the color diagram for upland cotton.

The color of opened cotton in the field can be adversely affected by excessive rainfall, freezes, insects, fungus, and soil or leaf staining. Cotton color can also be adversely affected by excessive moisture and temperature levels during storage, both before and after ginning.

Studies of fiber and spinning properties indicate that color reflectance is related to both fiber strength and yarn strength. As cotton color deteriorates due to environmental conditions, the probability for reduced fiber and yarn strength is increased. Color may also affect the ability of fibers to absorb and hold dyes and finishes.

Trash

Trash in raw cotton is measured by a video scanner, commonly referred to as a trashmeter. The trashmeter measures the amount of leaf and other particles from the stalk and extraneous matter such as grass. The cotton sample is scanned by the camera and the computer calculates the percentage of surface area occupied by trash particles.

Testing Environment

Because environmental conditions affect fiber properties, the temperature and humidity is very tightly controlled in AMS classing facilities. Temperature is maintained at 70 degrees, plus or minus 1 degree, and relative humidity at 65 percent plus or minus 2 percent. Cotton samples to be tested are allowed to reach moisture equilibrium (when a cotton sample no longer takes moisture from or gives moisture to the surrounding environment). Cotton samples to be tested in AMS classing laboratories are conditioned at least 48 hours before classing. Moisture content of the samples must be between 6.75 percent and 8.25 percent.

The growth toward more stringent standards for end-product quality, as dictated by consumers, has been an important element in establishing the relationships among classes of cotton, spinning performance, and product quality. Technological advances in textile production have sharpened the importance of the relationship between processing costs and fiber quality.

Poor quality fiber results in higher waste levels, increased ends down (interruptions in the yarn formation process), and more seconds in finishing operations. Manufacturers must have detailed fiber quality information to keep pace with increasing processing speeds and to assess the potential for cost-cutting innovations (see Table 2.2.4 for a summary of how different quality factors impact on processing characteristics).

Table 2.2.4 - Cotton quality factors and their effects on textile mill processing

Quality factor	Processing characteristics affected
Grade:	
Color	Dyeing, bleaching.
Trash	Processing waste, textile machinery contamination, product appearance, cotton dust levels.
Preparation	Processing waste, product appearance.
Staple length	Yarn and fabric fineness and strength, nep formation during processing.
Character:	
Fineness and maturity, yarn and fabric strength, waste, ends down.	Nep formation during processing, product appearance, processing.
Length uniformity	Processing waste, ends down.
Strength	Yarn and fabric strength, ends down.

2.2.6 Using Cottonized Flax

We can now consider the case of cottonized flax. When flax fibers are cottonized, the bundles of flax fibers (which seem like single thick fibers to the naked eye) are not only shortened to a length similar to cotton but they are also split into individual fibers sometimes called elemental or ultimate fibers. These ultimate fibers have theoretically a diameter and length surprisingly similar to cotton fibers and hence if the ultimate fibers can be separated cleanly from a bundle of flax fiber they can be spun quite easily on cotton system machinery. However, because ultimate flax fibers have thicker and more rigid walls, and are much less twisted and convoluted than cotton fibers, a yarn made from cottonized flax fibers can never be spun to as fine a yarn count as cotton fibers could be spun to.

The difficulty in spinning thinner "high count" yarns (e.g., >Ne20) from cottonized flax fibers is further exacerbated by the difficulty of separating the individual ultimate flax fibers from a bundle of flax fibers without doing damage to the ultimate fibers. To date, almost all commercial production of cottonized flax has been done using mechanical cottonizing systems. This is perhaps because processors use mechanical systems to regulate the length of the ultimate flax fiber so that they are similar to the length of cotton and most processors feel that since they use a mechanical system to regularize the length they may as well combine it with a mechanical system to split open the flax bundles into ultimate fibers[11]. However, when flax bundles are cottonized mechanically, it is impossible for the saw-teeth and pins used on the various rollers to exactly and precisely line up and split each bundle into ultimate fibers. Waste in the form of dust and short fibers are always created and the more unretted the flax, the greater the waste. (e.g., cottonizing well retted scutched flax tow may generate 20 – 30% waste whereas cottonizing underretted scutched flax tow could easily generate 40-60% waste). If the flax bundles have already been partially separated (i.e., if fine hackled tow is used instead of coarse scutching tow), the waste produced by cottonizing will be considerable reduced[12].

The amount of cottonizing waste that is produced is also influenced by the degree of "regularity" or "evenness" that the cottonizer wishes his final product to have. For example if a cottonizer wishes to sell a spinner that wants to use a high percentage of cottonized flax (e.g., >50%) to make a fine yarn (e.g., Ne30) then the cottonizer must set his cottonizing machinery so that the fiber length distribution is very tight (i.e., very consistent) and the number of unopened or half opened bundles is kept to a minimum. This, in turn, will mean that the cottonizing machinery will run somewhat slower (i.e., hourly throughput will be lower) and that waste factor (i.e., unacceptable short and long fibers) will increase compared to what will happen if a cottonizer sets his machinery to produce cottonized flax that can be used at a low percentage (e.g., 15%) in a blend and/or in yarns that are relatively thick (e.g., Ne8).

Most cottonizers of flax fibers have several grades of cottonized fiber to accommodate the needs of different markets for yarn. Very even length cottonized flax with a very high percentage of ultimate fibers is sold at the highest price (e.g., US$3,000 – 4,000/tonne). It would be normally sold to spinners who are making yarns finer than Ne20 or for somewhat coarser yarns spun on the open end (O.E.) spinning systems. Such yarns are normally used in fine apparel like shirts, blouses, and underwear.

At the other end of the grading spectrum, we have cottonized flax that has a relatively high dispersion of length and a relatively high number of unopened fiber bundles. This class of cottonized flax would sell for lower prices (e.g., US$1,400 – 2,000/tonnne), and cost the least to produce because the waste factor cost is the lowest. This class of fiber could not be used in an O.E. spinning system but it could be blended with other fibers and then spun on ring spinning systems. This type of cottonized flax would often be blended at low rates (e.g., 10-15%) to produce a coarse textured yarn for use in upholstery fabrics, drapery, or jackets. It could also be used at higher blend rates (e.g., 30%) to produce thicker yarns used in trousers. In between these two extremes of cottonized flax there are obviously other quality combinations of cottonized flax that are possible. For instance, some spinners have targeted a yarn market that wants to emphasize the natural color of flax by blending cottonized flax with cotton to produce a very natural-looking garment. In such an instance, the cottonizer must produce a cottonized flax product that has a very even color so that no color bands appear in the garment.

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[11] There are newer technologies to cottonize flax which involve enzymes, ultra-sound, steam explosion or chemicals but the author is unaware of anyone at present who is using one of these systems to regularly produce commercial scale quantities of cottonized flax.

[12] For brief descriptions of the various types of flax fiber and their traditional method of production, see Chapter 3

2.3 Financial Considerations

A cottonizer has normally three major costs. These are:

1) Raw material;
2) Processing costs; and
3) Waste.

If the cottonizer is near a specialty paper producer, he may be able to sell some of his better quality waste fibers for paper making. This would of course, reduce his cost of waste. Processing costs are affected, most of all, by the combination of machinery and labor that is selected when the cottonizer begins his operations. Cottonizers are quite secretive about their processing costs, but a range of US$400 – 700/tonne of cottonized fiber seems most likely based on information gained from interviews. Actual costs will, of course, vary with the location, the type of machinery, the fineness of the raw material, the type of cottonized flax being produced, etc. Cottonizers almost always use hackled or scutched tow which comes from well retted flax. Prices for such tow range from US$400 – 1,200/tonne depending on the quality and the year of purchase. To some extent, a higher quality of flax tow will reduce processing and waste cost so cottonizers have some flexibility in substituting lower or higher quality flax tow, depending on the price differential that exists at any point in time between lower and higher quality flax tows. Cottonized flax fibers could be made from well retted long line flax, however, long line flax is generally two to three times more expensive than tow and hence it is generally not cost effective to use long line flax as a raw material. Cottonized flax fibers can also be made, in theory, from unretted flax or partially retted flax (e.g., oilseed flax straw from Western Canada), however, because there is no retting or very uneven retting, the waste factor is extremely high (e.g., 50-80%) because of the great difficulty of separating the fiber bundles into ultimate fibers.

A cottonizer will generally make the highest margin per tonne when he sells fibers destined for the highest yarn counts, however, the volume demanded of high yarn counts (e.g., >Ne30) is much smaller than the volume demanded of medium yarn counts (e.g., <Ne24). The following chart (Figure 2-1) illustrates

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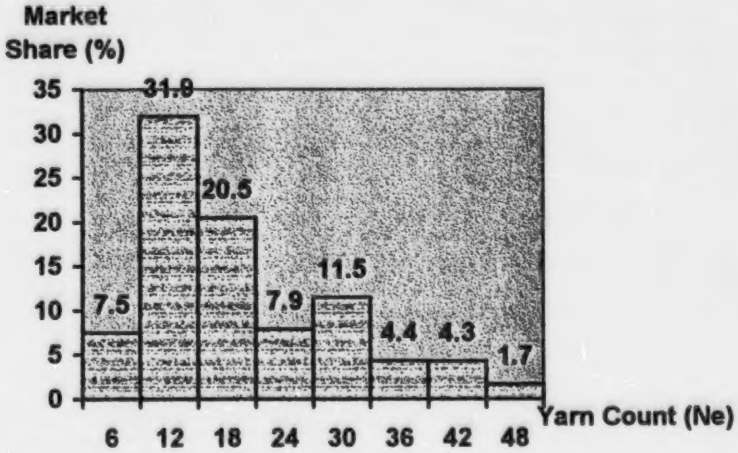
how medium count yarns dominate the demand for yarns, at least in terms of raw material used. This is partly due to the fact that jeans are relatively heavy items (i.e., use lots of fiber) and are made from yarns with counts of 12 to 18.

Figure 2-1 - Market share for different yarn counts



Sources: Kohler (1992) and Shenek (1993)

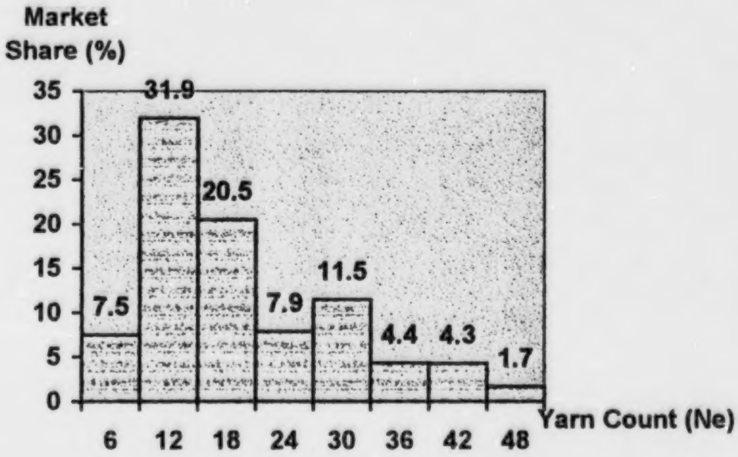
In the world of textiles, there are many exceptions but the following would be a general indicator of the major end uses for yarns of different counts.

<6	Upholstery, drapery, carpet, "special effect" yarns
6 – 12	Trousers, jeans, jackets, upholstery and drapery
12 – 18	Some trousers, skirts, table clothes
18 – 24	Shirts, household linen
24 – 30	Shirts, blouses, bedsheets, socks, underwear
30 – 36	Shirts, blouses, socks, underwear, bedsheets
>36	Shirts, blouses, socks, underwear, bedsheets

In general, long line flax can be used to spin pure linen yarns as fine as Ne30; flax tow can be used to spin pure linen yarns up to about Ne10 and cottonized flax can now be spun pure up to Ne8 and in 55:45 blends with cotton up to about Ne30. This means that if cottonized flax is blended with cotton, viscose, polyester or wool, it can be used in the vast majority of textile applications.

Cottonized flax fibers are not quite as soft as cotton but they absorb roughly 50% more moisture, are more durable and produce little or no lint. Historically, however, cottonized flax fibers have been more expensive to buy than cotton and are more difficult, costly and dirty to spin relative to cotton. Given these features, how medium count yarns dominate the demand for yarns, at least in terms of raw material used. This is partly due to the fact that jeans are relatively heavy items (i.e., use lots of fiber) and are made from yarns with counts of 12 to 18.

Figure 2-1 - Market share for different yarn counts



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However, it should be also pointed out that over the last two decades, more and more apparel is being made from knit rather than woven fabrics. This trend is expected to continue because knitting technology is becoming more sophisticated and cheaper and because knit wear is more maintenance free (i.e., little or no ironing needed) relative to woven wear. The trend toward more knit wear means a growing demand for yarns of a higher count and for yarns which are more even (i.e., knitting machines cannot cope with uneven yarns as well as looms). This will make it more difficult for cottonized flax to gain market share because it is harder to spin even, high count yarns with cottonized flax pure or in a blend. Furthermore, spinners, especially in developed countries, are using more and more O.E. spinning systems to produce yarn because, although O.E. systems have generally a higher capital cost than ring spinning systems, the labor requirements are lower and the yarn throughput per hour is generally significantly higher than with ring spinning. When O.E. systems are used, the fiber lengths and fiber diameters must be much more even than that required for ring spinning. In this regard, synthetic and cotton fibers have an advantage, to date, over cottonized flax fibers.

Fortunately cottonized flax fibers do have properties and characteristics that would make them very desirable blends with other fibers. Cottonized flax fibers are produced from flax, which, on a per tonne of fiber basis, probably requires not more than 5% of the pesticides needed to produce a tonne of raw cotton. This will make cottonized flax a useful fiber to include in textile end products targeted to markets that are environmentally concerned.

Small amounts of cottonized flax included in a cotton or synthetic yarn can be used to produce fabrics that have a home-spun old fashioned look. The demand for this type of look is very much driven by fashion and has led, in the past (e.g., 94/95) to substantial rises in the uses and price of cottonized flax. This type of demand is profitable to cottonizers when it happens but it is a fickle market and one that cannot be depended upon to help develop a long term, stable flax cottonizing industry.

Perhaps the biggest potential market for cottonized flax revolves around the fact that cottonized flax fibers can absorb roughly 50% more moisture than cotton fibers. This factor means that garments containing cottonized flax will feel cooler and more comfortable than pure cotton garments because moisture will be wicked away from the skin faster with a cottonized flax product. Tests have yet to be carried out to show conclusively what the minimum percentage of cottonized flax must be included for the wearer to feel a noticeable improvement in comfort. Based on rough rules of thumb for many other properties, some textile experts have suggested that the minimum required would be 30-35%. At this rate of inclusion, a medium to high standard of cottonized flax fiber would probably be required, particularly if the item were knitted. Higher inclusion rates may be used depending on :

1) the desired moisture absorbency rate;
2) the price of cottonized flax vs. the other fibers in the blend;
3) the technical difficulties encountered as more cottonized flax is used in the blend; and
4) export and import taxes, quotas and regulations[13].

The inclusion of cottonized flax fibers in a cotton blend would certainly improve the comfort of most end uses of cotton (e.g., apparel, towels, upholstery), however, given the historical price relationship between cotton and cottonized flax, the inclusion of cottonized flax would increase the cost of producing an item. How much of an increase? Since the cost of finishing a fabric and making it into a garment or other item are almost the same whether the fabric is cotton or a flax/cotton blend, any cost difference will come at the weaving, winding and spinning stages. Weaving costs may be somewhat more expensive (i.e., 10-20%) because loom speeds may be slowed down to reduce yarn breakage and subsequent fabric repair costs. For similar reasons, winding operations may be somewhat more expensive (i.e. 10-20%) because winding speeds are often slowed down to reduce yarn breakage and repair time.

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[13] Chinese flax/cotton blend garments sold in NAFTA countries almost always have at least 55% linen content so that the Chinese can have these garments classed as "flax blend" rather than cotton blend items. This reduces the Chinese export tax they have to pay and/or allows them to avoid having such garments included in China's quota of cotton garments which are allowed to be imported into NAFTA countries.

The biggest cost increases will come during the spinning stage. Spinners have reported reduced throughputs ranging from 10% to 60% when they start incorporating cottonized flax into their yarns. The amount of throughput reduction depends on such things as:

1) the percentage of cottonized flax being used;
2) the amount of non-desirable material (e.g. dust, short fibers, long and/or thick fiber bundles);
3) the fiber length distribution of the cottonized flax;
4) the fineness (i.e. yarn count) of the fiber being made;
5) the strength of the cottonized flax;
6) the overall consistency of the fibers within the given lot of cottonized flax;
7) the spinning system being used; and
8) the relative humidity within the spinning room.

Generally yarn production per spindle per hour will be reduced if:

1) the percentage of cottonized flax is high;
2) there is a high percentage of non-desirable material;
3) there is a wide dispersion of fiber lengths;
4) a fine yarn (e.g., high Ne or Nm counts) is being spun;
5) the cottonized flax is weak;
6) the fibers in the lot have very inconsistent properties;
7) an open end spinning system is used in conjunction with uneven fibers; and
8) the relative humidity is low and/or uncontrolled.

In addition to reducing spinning speed, the use of cottonized flax also creates higher spinning costs in the form of increased spinning waste and increased weight loss during bleaching. Spinning waste is higher because there are generally more very short or very long fibers in cottonized flax (i.e., a wider dispersion of fiber lengths) than cotton or synthetic fibers. Bleaching weight loss is greater because cottonized flax holds more pectin and waxes on the surface (hence, its color is beige rather than white) than do cotton or synthetics. The bleaching process dissolves and rinses these pectins and waxes away and hence bleaching weight losses are greater (e.g. bleaching losses for cotton may be in the range of 5-15% while cottonized flax may be in the range of 15-30%). When we add up the additional costs incurred in bleaching, spinning, winding and weaving we are probably looking at increased **processing** costs that would be 50-100% higher for a pure cottonized flax fabric compared to a pure cotton fabric. However, if we are using a blend of cottonized flax with cotton, the additional costs would obviously be pro-rated according to the percentage of cottonized flax in the blend.

Additional processing costs could be significantly reduced if cottonized flax could be made to physically have the consistency, cleanliness, fineness and strength of cotton. Thus spinners are often willing to pay more for cottonized flax which exhibits a clear resemblance to cotton (e.g., the best "grades" of cottonized flax are often more than double the price of the lowest grades of cottonized flax because the best grades of cottonized flax must closely represent the length and fineness dimensions commonly found in cotton).

At the present time, fabrics containing cottonized flax are selling from 50% to 150% higher than pure cotton fabric of a similar yarn count, density and weight. Some of this higher price is an actual reflection of the higher costs of cottonized fiber and the additional processing costs associated with it; some of the higher price is also the result of charging "what the market will bear" for a niche fabric that may be in fashion. The cost of fabric in an average garment can be 40% to 60% of the total cost of the garment, depending on the type of garment, labor costs, etc. Thus if the average cottonized flax/cotton blend fabric is double the price (i.e., 100% higher in price) of a pure cotton fabric and fabric costs represent 50% of the garment cost, than a garment containing cottonized flax would be theoretically 50% (50% of 100%) higher. Thus on the average, if a pure cotton shirt were to retail for $39.95 we could expect a shirt containing "55:45 flax:cotton" to retail for roughly $59.95 (i.e., 50% higher). Several representatives of large garment marketing firms have expressed the view that the demand for garments containing cottonized flax will not really expand unless the cost of the finished garment is no higher than 25% higher than a garment made from 100% cotton. If this is true, it means that the cost of fabric containing cottonized flax must be reduced. This, in turn, means that processing and raw material costs must be reduced.

Consider now how such cost reductions might come about. It will likely be difficult to reduce bleaching costs and weight loss because it is likely flax fibers will always be covered with a layer of pectin and/or wax which must come off in the bleaching process. The additional costs associated with weaving and winding yarn containing cottonized flax are almost totally related to the fact that cottonized flax yarns, to date, are generally more uneven than pure cotton yarns and hence are more likely to break if weaving and winding speeds are kept the same. Thus we are left with the spinning process as the major cost center that must be modified before yarn construction costs are reduced. In spinning cottonized flax, we are generally faced with a fiber distribution that is both more uneven than cotton and one in which we have to also cope with a wide range of fiber thicknesses due to the presence of unopened fiber bundles (i.e., it would probably not be an over-estimate to say that one can find fiber bundles that are at least five times as thick as single flax fibers). The wide dispersion of fiber lengths and the presence of varying diameters of fibers and fiber bundles means that not only do ring spinning systems have to be run slower to reduce yarn breakage (i.e., "ends down"), it also means that it is much more difficult to use a high percentage of cottonized flax in the faster, and generally lower production cost, open end or air jet spinning systems[14].

Research is being carried out now in several parts of the world to reduce the spinning costs of cottonized flax within the spinning plant. These include:

1) adding chemical additives (i.e., lubricants and softeners) to the sliver before it is spun to improve its "spinnability";

2) installing the newest, and hence the most precise, drafting equipment to maximize the chance of having a very even sliver and hence a very even yarn;

3) drawing and drafting the sliver more often than cotton yarn in an attempt to improve the evenness of the sliver;

4) increasing the relative humidity of the spinning room above what is normally used for cotton (i.e., since moisture tends to soften flax fibers, high humidity makes it easier for flax fibers to wrap and tangle around each other during the spinning process);

5) putting the cottonized flax sliver through a "combing machine" similar to that for combing cotton (Such a combing machine gets rid of most of the very short and very long fibers and hence reduces the dispersion of fiber lengths. This, in turn, allows a finer, more even yarn to be spun); and

6) modifying rotors and feed mechanisms so they can better cope with flax fibers that are stiffer and more irregular in length and diameter than cotton fibers.

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[14] The author has seen several samples of 100% cottonized flax yarn spun on an open end system from several different parts of the world but he is not aware of any open end spinner regularly producing large commercial scale lots of such yarn at this time.

Making the spinning process more efficient using techniques like those above will certainly help reduce the cost of fabric containing cottonized flax but their effectiveness at reducing cost is also very much dependent upon the cost and quality of raw cottonized flax that comes into the plant. Hence the raw fiber cost and the type of cottonized process that is used have a very important role in determining final cost of fabric containing cottonized flax. Is it likely that the quality of cottonized fiber will improve in the future and/or the cost of cottonizing can be reduced? If it does happen, it will greatly expand the market for cottonized flax. Thus this question is a very important one and will be dealt with in much more detail in the latter sections of Chapter 3 that deal with possible new cost structures for producing flax fibers and cottonizing them..

2.4 Survey Results

As part of this study, over 30 brokers, traders, spinners, weavers and retailers were contacted to get their impressions about cottonized flax. Many of their responses and reactions have been incorporated into other parts of this report. We have also summarized and combined their responses under the following question headings:

Why is flax fiber cottonizing capacity presently under utilized?

- demand not there because:
  - Price of cottonized flax fluctuates too much
  - Best quality cottonized flax is too high priced relative to cotton and viscose
  - Cottonized flax is dirtier to work with than clean cotton and clean viscose
  - Spinning efficiency drops from 95% to 80% when I start using cottonized flax because the quality of the fiber is not consistent enough
  - Russia and China are now selling linen fabric for prices that are as cheap or cheaper than fabrics from other origins that contain cottonized flax
  - There is no promotion and education regarding the benefits of cottonized flax at the wholesale or retail levels
  - Some spinners aren't aware they can buy cottonized flax
  - Fashion is not calling for much cottonized flax
  - Unless you can spin on the open-end (O.E.) system, the cost of high linen content blended yarn will approach the cost of lower quality pure linen yarn and, if that is the case, you may as well use pure linen yarn.
  - Cotton fiber is very cheap this year

Before you buy or use cottonized flax, what technical things do you need to know about it and how should these be measured or reported?

- You must know the technical and processing requirements of your equipment and the cottonized flax fiber you are going to buy. These include:
    - Average length of fibers
    - Distribution of fineness of fibers
    - Dye fastness
    - Minimum impurity content
    - Ability of supplier to give you the quantity and quality of the fiber that you need
- Same information that I get with cotton bales;
- What will be the color and shrinkage of the fabrics produced with cottonized flax?
- Information needed depends on end use
- How consistent is the color because if we use the natural color we do not want to see color bands in the finished fabric.
- Length distribution, fineness need to be measured with machine; strength can be felt by hand
- Really need to know if it will work in my machines
- The best but most time-consuming is to get large scale samples and make test runs
- Should try to measure as much as possible with cotton testing equipment because that is what people are most familiar with

What is the price of cottonized flax fibers now?

- The price depends on the quality and it varies from US$990/t to US$3,970/t at present but the price of a given quality can vary by 100% between years
- Now the qualities sold in the USA are US$1,200-2,200/t but some years ago they were up to US$4,400/t
- Thought the last price paid was US$1,760/t (i.e., $0.80/lb) but the cottonized fiber had too many big fiber bundles in it so couldn't use more than about 15% blend on an O.E. system for 12 English count yarns
- Price in North Carolina now is US$1,100-4,400/t (i.e., $0.50-2.00/lb) compared to polyester fiber now coming in from Asia at $617-838/t (i.e., $0.28-0.38/lb)
- The average price in East Asia now is US$1,500/t for cottonized fiber and US$2,500 for carded cottonized fiber but there is a wide range of qualities and prices. The price now is only about 60% of the price in 94/95;

- It is lower than in 94/95 but at that time they experienced a doubling of prices in a few months and they do not want that type of price shock again.

How important is price stability in reference to using cottonized flax?

- If you are a big spinner with low overhead costs, the cost of raw material is roughly 60% of your total cost so price stability is very important to big spinners who must plan and execute a marketing campaign to match production. Thus they must plan far ahead. Cottonized flax prices fluctuate quickly and in large percentage terms so this discourages cottonized flax from being used by big spinners.
- In the past the price of all types of flax fibers has varied more than cotton and this is the most important high-risk factor faced by spinners. We think this is because:
  - The primary market for flax fibers is concentrated in Europe;
  - The number of suppliers is very small and competition is absent;
  - Most of the cottonized flax is tied up with fashion trends and little is used at present in non-fashion applications;
- In USA cottonized flax is usually used in blends of 5-30% flax to give a certain appearance whereas in Europe it is often used in blends of 50% or more flax to give improved comfort. At low blend rates spinners can cope with wild fluctuations in price but this is not the case at higher blend rates.
- Some potential users will not buy cottonized flax now unless they have a chance to fix the price one year in advance because they got "burnt" in 94/95
- High prices or wildly fluctuating prices are not important if fashion demands it and consumers are willing to pay;
- The industry's low capacity to produce fiber leads to a rapid rise in price when fashion creates a demand for cottonized flax. At such times spinners can pass on higher costs to consumers, however, supply is often restricted at high prices because, in the short run, a cottonizer cannot increase production if his plant is already running three shifts every 24 hours.
- As demand is driven mainly by fashion, flax tow processors will know when they can raise prices to cottonizers. This, in turn, accentuates the rise in price of cottonized flax.

Open-end (O.E.) spinning systems are becoming increasingly popular because of their higher throughput. What are the present limitations to using cottonized flax on O.E. systems?

- Yarns spun on O.E. systems are usually coarser and looser than yarns spun on the traditional ring-spinning system. With the exception of jeans and upholstery yarns, there is not always a market demand for this type of yarn.
- O.E. systems produce softer and weaker yarns and these are hard to use in fine knit wear like socks and underwear.
- Standard O.E. systems have to be modified if high blends of cottonized flax are to be spun. Most spinners are unwilling to make these modifications unless they are assured of continuous demand.
- Cottonized flax is dirty and the dirt gets into the spinning turbines and reduces the potential throughput. This, in turn, reduces the advantage of O.E. spinning relative to ring spinning.
- Cottonized flax fibers are generally less consistent than cotton fibers and also react more with moisture than cotton or synthetics. The O.E. system, to be efficient, needs more perfect fibers than the ring-spinning system. Hence spinners not used to spinning flax based fibers will have a harder time producing a consistent yarn when they use flax-based fibers.
- The coarser fibers keep flying around inside the turbine and reduces throughout by at least 20%.
- The limitations are the same as those for ring spinning. Cottonized flax fibers are not as consistent as cotton or synthetic fibers and hence require more labor to watch the machines. This, in turn, often means yarn and fabric costs that are not competitive with imported pure or blended yarn or fabric.
- Blended yarns made with the O.E. system show little or no "linen look" and thus are not desirable to designers who are promoting the linen look.
- About 20 % of cottonized flax (usually in blends) is spun on the O.E. system and about 80% is ring spun so this should show that there are many limitations.
- The staple length and fineness of average quality cottonized flax is not consistent enough to use in older O.E. systems. If spinners with older systems in the USA want to spin cottonized flax, they would need to buy different rotors, cones, etc. They would probably be better off buying O.E. flax blend yarn from spinners off-shore who specialize in this type of yarn.

- When spinning cotton, viscose or polyester, the cost of labor with the O.E. system is about 25% of ring spinning systems and, overall, the total cost is about 50% less. I am a North American spinner and the only way I can compete with Asian spinners is to use the O.E. system. I won't use cottonized flax unless I can easily fit it into my O.E. system.

What would the price of cottonized flax fiber have to be before you would consider using cottonized flax fiber in a long-term production run?

- Must be about 25% less than the price of cotton.
- Existing equipment in mill limits the amount of cottonized flax we can use to 15% blends and at this low a blend rate, the price is not important.
- Demand must eventually come from consumers, low priced raw material is not enough to make spinners use flax.
- If it was 50-65% of cotton price, there would be many spinners seriously thinking about using it.
- To sell more cottonized flax, the producers of it need to improve consistency, stabilize price and convince designers and spinners that a new fabric is available consistently and at a stable price.
- Fabric made with O.E. spun yarns would be roughly 60% of cost (including raw material) of pure linen fabric made from traditional ring spun yarns.
- If it was US$1.00/lb (i.e., about 40% more than cotton) and consistent in staple length (i.e., about two inches long like viscose) then the market would be much bigger, especially if the fiber fineness was denier 1.0 to 1.2.
- Generally speaking the price of O.E. spun yarn with roughly 30% flax content is about one third the cost of traditional wet ring spun 100% flax yarn.

2.5 Market Size and Growth Potential

It is difficult to estimate exactly how much cottonized flax could be sold at lower prices because, to date, there has never been a large supplier of cottonized flax who was willing to sell for relatively lower prices. At the present time the volume of cottonized flax fiber produced and traded internationally is in the range of 20-40,000 Mt at prices varying between US$1,500-4,000 per tonne depending on the quality and year. This represents roughly 0.1 to 0.2% of the annual weight of cotton consumption in the world.

A significant portion of the world's cotton is grown in developing countries that consume domestically most of their production. Some of them have restrictions or lack of foreign exchange that would severely limit the amount of cottonized flax they could buy even if cottonized flax prices fell significantly. Although cottonized flax can be used to produce more comfortable garments than cotton; can be produced in a much more ecologically friendly way than cotton and potentially can be produced cheaper than cotton; cotton is still more consistent and easier to spin. Hence, cottonized flax could not, in the next ten years, be expected to replace cotton in at least two thirds of the world's cotton markets. It will, instead, be for the most part, a complimentary fiber to cotton. Given these assumptions, we have tried to estimate demand under several prices scenarios. The base case scenario assumes the price of mid-quality cottonized flax[15] drops to US$2,000 per tonne (i.e., 25% higher than the 10 year average cotton price). We then estimated the percentage of the cotton market that could be replaced with cottonized flax, in major cotton markets, after several years of market development (see Figure 2.5.1). This generated a projected consumption of cottonized flax within ten years of 0.4 to 1.0 million tonnes. We also took this lower bound estimate and extrapolated from the base case scenario to graphically illustrate the likely market potential at lower prices of cottonized flax. The results of this are shown in (Figure 2.5.1). We can see that the market for cottonized flax will increase dramatically in terms of volume as the price of mid-range quality cottonized flax approaches and drops below that of cotton. This is because, at such price and volume levels companies making spinning equipment will likely introduce modifications to spinning equipment that will allow cottonized flax to be more easily spun at higher blend rates which will, in turn, encourage spinners to start using richer blends of cottonized flax.

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[15] Mid-quality cottonized flax could be used in blends of about 30% flax; a high enough percentage to give a linen look and enhanced comfort.

Figure 2-2 - Estimated demand for cottonized flax

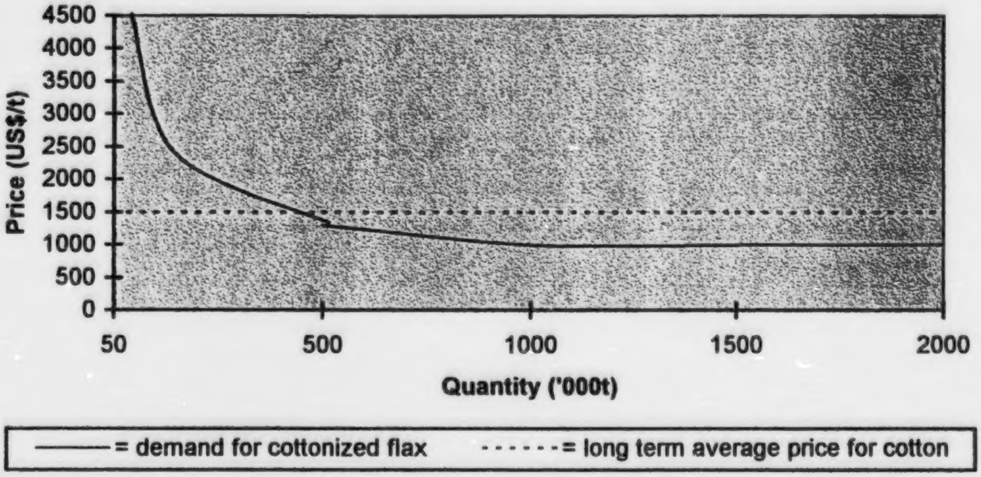

Table 2.5.1 - Estimated market shares for cottonized flax /a

	Raw Cotton Use /b Mt	Lowest Expected Share %	Highest Expected Share %	Lowest Expected Quantity Mt	Highest Expected Quantity Mt
USA	3.0	2%	5%	.06	.15
China	5.0	3%	7%	.15	.35
India	3.0	3%	7%	.09	.21
S. America	3.3	2%	5%	.07	.17
Japan	0.4	1%	3%	.01	.01
EU-12	1.1	2%	5%	.02	.06
Other	3.3	1%	1%	.03	.03
TOTAL	19.1			.43	.98

a/ assuming cottonized flax fiber sells for 25% more than cotton and there is at least five years to develop markets.
b/ Based on information in USDA's PSD database, Mt = million tonnes
NOTE: Market shares could be significantly higher if the average quality of cottonized flax improves and/or its price, relative to cotton, drops.

In addition if cottonized flax were to become a bigger part of the spinners program, it would become more difficult for them to switch out of it again, even if the price of cottonized flax were to rise again. This is because, as volumes increase, spinners become more experienced with it and can therefore become more productive using it. With increased production, some new customers are obtained that may not want to switch back to other fibers once they have tried cottonized flax. Thus the bigger the market share that cottonized flax takes in a spinner's production line, the more difficult it is to switch away from it. Thus price and volume are both important in getting spinners to expand the variety and volume of products they make from cottonized flax.

When a spinner decides to use cottonized flax, there are several things that must be considered in addition to price and volume. In terms of capital costs of equipment, anyone who has a traditional ring spinning cotton system can process cottonized flax without any major additional equipment. Open end cotton spinners will not need modifications if they stick to low blend rates and/or coarse yarns. They will, however, have to make some modifications if they wish to spin high blend rates and/or finer count yarns. Cottonized flax is spun, woven and dyed like cotton, however, processors often have to slow down their fiber preparation and spinning machinery by about 20%. This loss in efficiency is normally more than compensated by being able to sell the yarn at a higher price than pure cotton yarn.

The most difficult problem encountered by a cotton spinner who wants to incorporate cottonized flax into his line of yarns is the difficulty of getting a regular supply of consistent fiber. Flax is a natural fiber and hence has variations in color, fineness and cleanliness depending on the year and the location. Since spinners are very concerned with being able to supply consistent yarns to weavers and knitters, a spinner will try not to rely too much on any one supplier. Thus, if the cottonized flax fiber sector is to grow, it will need, among other requirements, an increasingly diverse range of producers of cottonized flax. This bodes well for the potential new suppliers of cottonized flax that may be located in the Canadian prairies.

In summary, the market potential for cottonized flax could be easily ten or twenty times larger than it is today and still represent only 2.5-6.0% of the world cotton market. However, this will not happen unless:

1) the range of qualities becomes tighter and more similar to cotton;

2) more promotion is carried out;

3) spinners become convinced that supply volumes can grow dramatically and in a stable fashion; and

4) prices drop and become more stable.

These requirements are inter-connected in several ways to the supply side of the cottonized flax market and the possibilities of addressing some of these issues are presented in Chapter 3 and subsequent chapters of this report.

3 Supply

3.1 Existing and Potential Suppliers

To date, cottonized flax has commercially only been made from hackled tow or better quality scutched tow that result from the traditional linen production system. It is thus important to have a brief overview of this system and some of the terms and definitions that are used within this industry

3.1.1 The Traditional Linen Production System

Linen is made on SPECIALIZED spinning and weaving equipment from the "long lines" of fiber that are extracted from the stems of the flax plant (*Linum usitatissimum*). These long lines of fiber are from 30 to 120 cm in length and can only be spun or woven on less than 5% of the world's spinning and weaving equipment. The following is a brief description of the processes and terms that are used in the production of traditional linen products.

Retting refers to the process of allowing flax straw to partially decompose or decay to the point where the fibers in the stems of the straw can be easily separated from non-fiber material within the stem. When flax straw is retted the microbes release enzymes which dissolve the pectins which hold the fibers within the stem of the straw. If flax straw is not retted enough, the fibers cannot be easily separated from the straw (i.e., under-retting) and if flax straw is retted for too long a period the fibers become weak (i.e., over-retting). There is thus an optimal amount of retting that is needed for each batch of straw to produce the maximum amount of strong fibers. After flax straw is retted, it is dried before processing. Over the centuries number of retting systems have been developed. These include the following:

1) **Pool or dam retting** was formerly very common in Europe and especially in Ireland. In this method, flax straw was bundled and placed in stagnant pools of water for ten to fifteen days before the bundles were taken out and placed in fields or on grass to dry. It has been reported that this method often caused over-retted and hence weak and brittle fibers. Pool retting darkened the flax fibers and gave them a bluish-gray color. This method has almost totally disappeared because it was very labor intensive and environmentally unpleasant.

2) **Stream retting** is said to have generally produced the best quality of fiber because the process of decomposition could be easily controlled. Bundles of straw were weighed down in streams of cool, running water for five to fifteen days before the bundles were taken out and

placed in fields or on grass to dry. This method produced strong, superior linen of a pale yellow color and was used extensively in the River Lys in Belgium. This method has also disappeared in Europe because it was very labor intensive and polluted streams.

3) **Vat, tank or mechanical retting** refers to a process in which bundles of flax straw were immersed in wooden, concrete or plastic vats of water at temperatures ranging from 25 to 37 degrees Celsius. After soaking for four to six days the straw is removed from the vats and passed between rollers to crush the decomposed straw as clean water flushes away the pectins, gums and other impurities. The bundles were then taken and placed in fields or on grass to dry. About 90% of the fiber flax crop in China is still retted in this manner.

4) **Chemical retting** refers to the use of chemicals in the tank retting system to shorten the retting process. Past experience has shown that chemicals often affect the strength and color of flax fiber. Traditional methods of chemical retting have included the use of soda ash, oxalic soda or caustic soda in warm water or the use of dilute sulfuric acid in boiling water.

5) **Dew retting** refers to a process in which the flax straw is first pulled or cut and spread on a field or even on grass. The straw is then exposed to heavy morning dew and dry, sunny afternoons for three to four weeks until the fibers separate easily from the non-fiber parts. It is then gathered in bundles or bales and stored until it is processed. It appears that dew retting got started in Russia and then spread to Western Europe. It requires relatively little labor (compared to other retting methods), is non-polluting and often produces the finest fiber. However, this retting system is the most dependent on weather conditions and is therefore the most difficult to control. In spite of this drawback, it is now, by far, the most common retting system used in Europe.

6) **Enzymatic retting** is a newly evolving technique based on the tank retting system that involves treating straw or roughly extracted fibers with a solution containing enzymes (either by soaking or spraying) that have been identified as being effective in decomposing flax straw. (Some trials have also been made with treating straw that is still in the field with a solution containing selected enzymes.) Enzymes have the potential to be more gentle than chemical retting because the enzyme should be inactivated when all the binding pectins have been dissolved and hence reduce the possibility of becoming over-retted. Small trials have shown encouraging results, however, to date the cost of most commercially prepared enzymes has made this method too expensive for commercial use. However, the cost of producing enzymes has

been declining and the technology of how to use them more effectively has been improving. Thus enzymatic retting could become commercially viable in the near future.

In the traditional flax fiber processing industry, when the partially decomposed (i.e., retted) straw is dry, it is crushed by passing it through fluted iron rollers. This **breaking** operation reduces the non-fiber parts of the stem to small pieces called **shives**. It also produces some short fibers mixed with bits of root, seed holders, leaves and shives. This is called **breaker tow** and is often used in specialty paper production. Shives are removed from the flax fibers through a process called **scutching**. Traditionally this process was carried out by hand using wooden paddles. In modern flax fiber processing mills, breaking and scutching are combined into one operation by passing the retted straw through a series of differently configured rollers and then past sets of large diameter turbines which scrape any remaining shives and weaker fibers off the stronger long fibers. The scutching process produces shives, long fibers called **long line fiber**, and short fibers called **scutching tow**. Long line fiber is then combed by machine or **hackled** to straighten the long fibers, to break coarser fibers into finer fibers, to leave the fibers in a parallel position and to remove fine short fibers called **hackling tow**. To produce very fine long line fiber, hackling may be repeated several times using a succession of finer combs. The hackled long fiber is then **drawn** several times to produce increasingly finer and more regular band of fiber called a **sliver** which can then be drawn even thinner and lightly twisted into a **rove**. Generally the more times the fiber bands are drawn the finer and stronger the yarn because the number of "weak points" are reduced with more drawing.

The rove can either be spun directly on the dry-spinning system or be chemically treated (e.g., **scouring** by boiling with soda or **degummed** with dilute bleach solution) and then spun on the wet-spinning system. When flax fibers are scoured they retain their natural grayish beige color; when they are degummed with bleach they become an off-white cottony color. Wet-spinning requires more steps and materials than the dry-spinning system and is, as a consequence, more expensive. However, when flax rove is scoured or bleached it becomes finer and stronger and can thus be spun into finer, more expensive yarns. In the **wet-spinning system** the rove is twisted and then passed through a small container of heated water before being taken up by the spinning mechanism. In the **dry-spinning system** the rove is simply twisted and taken up directly by the spinning mechanism.

In total, there is roughly one kilo of assorted qualities of tow produced for every kilo of long line fiber produced. Traditionally, if the scutching tow was to be used for making yarn, it would be put through at least two **carding** operations, one for "breaking" the fiber and one for "finishing" the fiber into a regular **sliver** ready for spinning into yarn. Such a sliver could be described as a parallel band of very parallel, medium staple fibers that can be further drawn and then spun into yarn using the **dry-spinning** system. The same process is used to turn hackling tow into dry-spun yarn except that hackling tow does not need to pass through a breaking card (i.e., it can go directly to a finishing card). Flax tow that cannot be used for textile purposes is used for making specialized paper products (e.g., currency, cigarette paper), geotextiles and plastic composites. Hackling tow is finer and more valuable then scutching tow which is, in turn, finer and more valuable than breaker tow.

3.1.2 Market Shares and Trends

For the last few decades the Former Soviet Union (FSU) has been the dominant producer and processor of flax fiber and textile goods made from flax. This has continued to be the case in the 1990s. However, the FSU exports very little of its output and imports very little from other sources, hence it is very much a "marketing island." Flax fiber from the FSU is also, for the most part, of lower quality than fiber from France and Belgium and hence prices for flax fibers from the FSU are relatively low. Relatively speaking, the Chinese have done the best job at improving the quality of their flax fiber but they have still not approached the quality and value of flax fiber from France and Belgium.

In the last decade, world flax fiber output has continued to decline to the point where production is slightly less than 50% of the level in 1986. The greatest percentage decrease has been in Eastern Europe but the biggest absolute decreases have been in the FSU and China. Western European production has remained relatively stable, largely because of the high subsidies that exist for growing and processing fiber flax products and because there is little political pressure with the EU to make any significant changes to this system of subsidies for flax or other agricultural products.

At the present time, almost all the fiber produced from fiber flax is used to produce linen. However, different regions and countries of the world have different end use patterns. For instance the FSU produces and uses most of its linen in the form of household items (e.g., bedsheets, table cloths) and for industrial use (e.g., rope, canvas); the EU, China and South America devote the majority of their linen to production of higher value clothing. Although the quantity of household goods made from linen exceeds that made into clothing, the retail value of linen in clothing is just as high as the retail value of linen in household goods. In terms of "added value" it is estimated that only about 10% of the final retail value of a linen article is added between the time the crop is grown and the raw fiber is processed and stored; a further 25% is added by spinning, weaving and finishing and the remaining 65% is added by the wholesalers and retailers.

Most of the world's capacity to process raw fiber flax straw is now in the FSU, China and Western and Eastern Europe. However, the number of hackling machines and flax spinning machines is spread more evenly between the FSU, China, Eastern Europe and Western Europe. In fact China has continued to increased its spinning capacity to the point where it now has more wet spindles than all of Western Europe, yet the Chinese capacity to process raw flax straw is much less than in Western Europe. The resultant implication is that China must either grow and process a lot more of its own flax fiber or import rough or finished flax fiber.

Western Europe, France, Belgium and the Netherlands account for almost all the area planted to fiber flax and process almost all the raw straw. However, a significant portion of the resultant fiber is spun into yarn in Italy, the United Kingdom (i.e., Northern Ireland) and Austria.

It has been estimated that there are about 10,000 farmers growing fiber flax in Western Europe, about 200 firms processing flax straw to extract and purify the fiber and less than 25 firms involved in spinning yarn for linen production. The average fiber processing firm has about 10 employees while the average spinning facility has about 200 employees. This means that about 7,000 jobs in Western Europe are directly created by processing flax fiber to the yarn stage and another 10,000 farmers receive income from growing fiber flax. The existence of these jobs has been used, in the past, to justify farm subsidies for fiber flax production that are sufficiently high to keep farm production levels relatively constant.

3.1.3 Relevance to the Projected Supply of Cottonized Fiber Flax

The production of pure linen products made from long line fiber has remained relatively stagnant for the last decade[16]. There are at least two main reasons why long line flax consumption has remained relatively unchanged. First, the production of pure linen requires an investment in spinning and weaving equipment that can only be used for long line flax fibers. The owners of spinning and weaving mills know that textile fashions change and that even though pure linen might be fashionable this year, three years from now it could be out of fashion. When pure linen goes out of fashion, long line spinning and weaving equipment sits idle and ties up capital and space that could be used for textile products that are in fashion. This is unlike investments in short staple "cotton system" equipment that can be used for all pure and blended short staple fibers. No matter which short staple fiber is in fashion, "cotton system" equipment will not sit idle since it can be used to process any short staple fiber. Thus the owner of a spinning or weaving mill must really believe in the long term future of pure linen before they will make new investments in equipment to handle long line flax fiber.

Second, although pure linen clothes are cool, strong and durable, they also take on and retain wrinkles very easily. In the last decade, it has generally been unfashionable to wear clothes that have a large number of prominent wrinkles. This means that people wearing pure linen garments have to iron them often.

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[16] Production of pure linen knitwear, particularly in China has taken up much of long line flax fiber formerly used for weaving pure linen fabric.

Many people who can afford to buy pure linen clothes do not have the time to iron their clothes often. Thus more and more of them choose, instead, to purchase clothes made of cotton/synthetic blends. These blends have much of the coolness and comfort of cotton but the easy care (i.e., non-wrinkling) features of synthetics. Thus although the world population continues to increase, per capita consumption of pure linen products has decreased and resulted in a stagnant total demand for pure linen clothes. Cottonized flax fiber blended with other materials could seriously erode the remaining market for pure linen clothing and household goods.

In the last decade China has steadily increased its capacity to wet spin flax fiber to enable it to produce higher end linen garment and household products that could compete with the output from Western Europe. However, the area and output of fiber flax in China has decreased and the number of hackling machines in China has not increased at the same rate as the number of wet spindles. To make a profit from increased spinning capacity the Chinese will almost certainly try to import as much raw flax fiber as they can from whatever source that they can. If some of this flax fiber is cottonized, so much the better, because they can then expand the manufacture of blended flax fabrics and garments for export and domestic markets.

3.1.4 Existing and Potential Suppliers of Cottonized Flax

In all the traditional fiber flax regions of the world breaker tow, scutching tow and hackling tow are only produced when long line flax fiber are produced. These regions (with the exception of part of the FSU) have high opportunity costs for land and could not afford to produce flax tow without also producing long line. In contrast lower quality breaker tow can be produced, not only during long line production, but also from fully mature, under-retted straw like that produced by Canadian oilseed flax farmers.

In Western Europe the biggest processor of cottonized flax is located in Northern France and can produce 400 to 500 tonnes per month of cottonized flax. An additional six or seven processors in France, Belgium and Italy can each produce 200-250 tonnes per month if conditions warrant. This gives a capacity in Western Europe of 20,000-27,000 tonnes annually. In Eastern Europe and Russia, it is estimated that capacity is less than half of Western Europe. In China it is estimated that there are only three or four high quality cottonizing facilities but several dozen plants that produce roughly cottonized products using simply modified cotton cards. Taiwan has at least two cottonizers left and there are several in the Koreas. India also has some cottonizing facilities. Data on installed capacity and actual capacity in production now is not published and even brokers of flax who sell to cottonizers do not have the full details on all existing and potential cottonizers. A reasonable guess would be that capacity and production outside Western Europe is not more than one to two times as large as that in Western Europe. This would give an upper bound estimate of 90,000 tonnes annually of capacity and a more conservative estimate of 30-60,000 tonnes of actual production.

In the last few years, capacity in Western Europe has been under-utilized; largely because fashion has not called for much cottonized flax.

However, should the demand for cottonized flax rise significantly, Western European cottonizers could find themselves short of suitable raw materials for mechanical cottonization. This is because, at present, almost all the production has come from cottonizing the higher quality tow that are produced in Western Europe during the production of long line fiber for linen production. European farmers who grow fiber flax compare the net return they get from growing fiber flax with the return they can get from growing seven to ten tonnes of wheat sold at the EU domestic wheat price. From a Western European grower's point of view, growing fiber flax only makes sense if it can be sold for the production of long line fiber, which carries with it a significant internal EU subsidy. Thus, to date, the supply of cottonized flax fiber, has been relatively unresponsive to changes in cottonized flax fiber market prices.

Western European producers of cottonized flax are constrained by the amount and types of tow that is available on the market every year and by the type of tow that they have in storage. This is because the weather patterns in different years produce different qualities of tow; hence the really successful cottonizers keep tow for several years on hand to allow them to blend different tows to meet the end-use requirements of specific customers. Thus one of the keys to being able to generate profits cottonizing at present is to have enough knowledge and raw materials to be able to produce a tailor-made cottonized flax fiber for each customer.

The reader might ask why Europeans don't simply stop producing long line fiber and start producing only cottonized flax fiber so that it can be spun pure or in blends. However, the flax spinning and weaving industries in the EU employ over 5,000 people at present. Flax fiber processing is an old and established industry with a very long tradition. At present the EU has few spinning mills left that could spin blends containing cottonized flax fiber. The Europeans also know that their flax textile industry, from farm production to garment making is highly subsidized. Under the GATT, such subsidies will be increasingly done away with. Some potential cottonizers in Europe are, no doubt, withholding any further investment while they wait to see if the fiber flax industry will be significantly hurt by changes in EU subsidies. If only cottonized flax were produced it would mean that most of the people in the flax processing industry would lose their jobs unless new mills were built and new equipment purchased. Otherwise most of the cottonized flax fiber would be exported to areas like East and South Asia where there are huge, low cost spinning and weaving industries.

Thus the present structure of the fiber flax industry in Europe greatly restricts their ability to produce significantly larger quantities of cottonized flax at lower prices.

Flax does well only in cool temperate climates and hence is restricted to the Northern Great Plains of North America, West Central Europe, parts of Eastern Europe and the FSU, parts of Northern China and areas in Chile and Argentina. Given the high gross margins that can be earned from growing cereals in west Central Europe, it is unlikely that there will be any significant increase in fiber flax production there. Eastern Europe and the FSU could certainly expand production but, for the next five to ten years, new investment in agriculture is likely to be relatively limited because investments in other sectors of the economy (e.g., the service sector) generally offer much better returns than investments in agriculture. Fiber flax production in China has been dropping from a high of about 320,000 Mt in 1987 largely because peasants have found their labor can generate more income per hour producing crops other than labor-intensive flax fiber.[17] This is similar to the trend that has been observed in the FSU and Eastern Europe Given the low wage rates and high cost of capital that exists in Eastern Europe, the FSU and China, it is unlikely that new production methods would vary greatly from the traditional labor intensive system. As labor costs rise, it will be increasingly difficult to attract workers into this industry in these production areas and hence expansion will likely be constrained.

European cottonized flax producers would be severely threatened if a new non-European supplier (e.g., Canada) were able to offer large quantities of consistent quality cottonized fiber at relatively constant prices. To do this, the new supplier would require access to large amounts of flax straw at relatively cheap prices per tonne of actual fiber, suitable processing techniques and people skilled at producing and marketing cottonized fiber. With suitable research, development and commercialization work, Canada could turn into such a supplier. Raw materials are available and/or can be produced cheaply and technology and people skills can be developed. Thus the potential to develop a cottonized flax industry in Western Canada could present a great long run opportunity for farmers in the Canadian prairies to develop a new crop with market forces that are quite unrelated to the food industry.

The greatest competition that potential Western Canadian producers of cottonized fiber flax would face would likely come from:

1) American producers in cool northern states like North Dakota, Minnesota, Connecticut and in southern states where flax could be grown as a winter crop (e.g., South Carolina, Texas);

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[17] This decreased volume has been made up by an increased volume of flax fiber imports from Western and Eastern Europe, FSU and Egypt.

2) Producers in other parts of Canada (e.g., Quebec, New Brunswick); and

3) Producers in Chile and Argentina.

All these areas have suitable weather conditions and the areas in North America have relatively easy access to the research funds and large scale farm equipment that could turn them into low cost cottonized flax producers.

3.2 Technical Considerations

When flax fibers are cottonized, the fibers are processed so their length and fineness becomes more similar to cotton. This technology has evolved over a number of decades and, to date, is a mechanical system designed to put good quality flax tow into a form that can be spun on the cotton system. The most common cottonizing method requires that tow be carded and cut to length before the cottonizing process. The cottonizing process then involves passing the aligned fibers through a series of cylinders rotating at different speeds which have different types of pins on their outer surface. At each cylinder a suction mechanism (i.e., an **aspirator**) is placed to suck up the fine fibers into an overhead tube where they are **condensed** by a perforated roller so that they can drop in an even cascade down onto the next cylinder in the line.

A **cottonizing line** consists of from five to seven cylinder/aspirator systems set up in consecutive order. Each cylinder rotates at a different speed and/or has a different set of pins. During the cottonizing process from 20 to 60% of the original weight of flax tow turns into dust and/or very short fibers. Some of this waste can be used by paper makers or in compressed fire logs but much of it is dumped for compost.

The actual amount of waste produced depends on at least four factors:

1) The fineness and strength of the flax fiber used as raw material;

2) The consistency of fineness and length desired in the resultant cottonized flax;

3) The skill and experience of the machine operator; and

4) The system of cottonizing that is used.

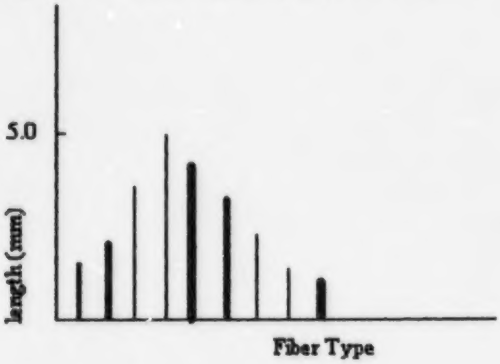
Cotton fibers grow as **single** fibers from the seed coat of ripening cotton seed; in contrast flax fibers are formed as part of fiber **bundles** inside the stems of flax plants. To make cottonized flax, the bundles of flax fibers must be separated, as much as possible, into individual fibers like cotton fibers. Once they are separated into individual fibers (i.e., **ultimate** fibers), flax fibers are roughly the same length as cotton fibers. The most difficult and expensive part of cottonizing flax is to split or separate the fiber bundles; the regulation of length is relatively much easier and cheaper. Flax tow which is both strong and finely divided is the preferred choice of cottonizers since it will be faster to cottonize and produce less waste than flax tow which is weak and/or not finely divided (e.g., over or under retted flax). Thus, although it is more expensive, cottonizers prefer to use hackled tow or best quality scutching tow instead of lower qualities of tow that may be considerably cheaper. The finer and stronger the tow, the less waste and consequently the more cottonized flax there is to sell.

If a cottonizer wants his final product to have a very high percentage of single fibers and to have a very tight range of fiber lengths, he must run his machinery more slowly to allow more accuracy and be willing to set his machines so there is a higher rejection rate of fiber bundles (as opposed to single fibers) and long and short fibers. This will, in turn, produce more waste, particularly if the tow is not fine to start with. The strength of flax fibers, the strength of the pectins and the brittleness of the shives are all greatly influenced by the moisture content of the fiber and the air in the processing room. Cylinder speeds, air speeds and gap spacings can also have a large effect on the amount of waste that is generated during the cottonizing operation. Since these parameters can be adjusted by the machine and/or plant operator; their skill and experience will affect the percentage of waste.

At the present time most cottonized flax that is produced relies on the mechanical action of closely spaced pins to tear the flax bundles apart to produce single fibers. Since it is very difficult to totally control the flow of fibers through very finely spaced pins; a considerable amount of waste is produced as single fibers may be bruised too severely (and hence broken) and fat fiber bundles may not be bruised or sliced enough. Newer cottonizing technologies attempt to address this problem by using methods which minimize the amount of mechanical action needed. These technologies include the use of such things as enzymes, steam explosion and ultra sound. They will be discussed more in Section 3.3.

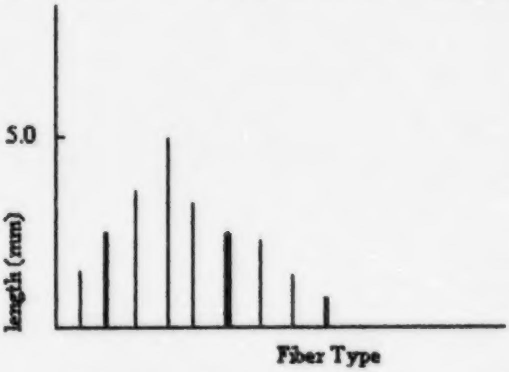
The following four stylized fiber diagrams are used to help the reader visualize the types of cottonized flax that can be produced:

Figure 3-1 - Low quality cottonized flax



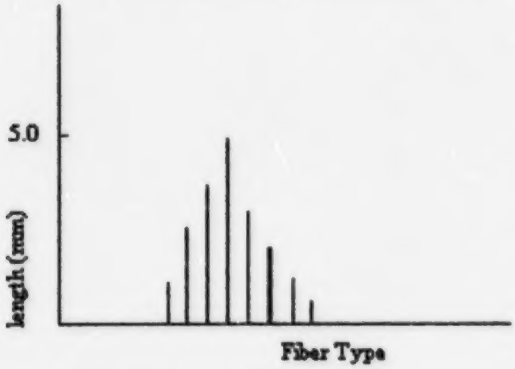
- large range of length
- mixture of fiber widths (i.e., many fiber bundles)
- use restricted to low bland rates and coarse yarns
- only ring spinning
- US$1,400-1,900/tonne

Figure 3-2 - Medium quality cottonized flax



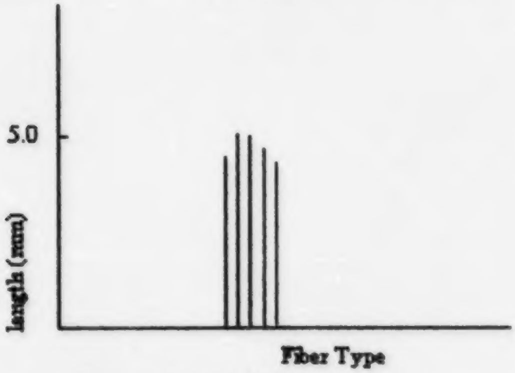
- tighter range of lengths
- fewer fiber bundles
- use restricted to moderate blend rates, (<55%) medium or coarse yarns
- ring spinning and some O.E. spinning possible
- US$1,800-2,300/tonne

Figure 3-3 - High quality cottonized flax



- quite tight range of lengths
- very few fiber bundles
- can be used at high blend rates with medium yarns
- spinning on both ring and O.E. systems possible
- US$2,500-3,500/tonne or more

Figure 3-4 - Ideal quality cottonized flax



- very consistent in length
- no fiber bundles
- could be spun pure to make medium and fine yarns
- could be spun on both ring and O.E. systems
- ideal price range would be at least 25% less than cotton to stimulate demand

3.3 Financial Considerations and New Technologies

The present and future potential demand and supply of cottonized flax are closely linked (see Chapter 2). At the present time world demand is limited to less than 100,000 tonnes annually with prices of middle and high quality cottonized flax being 50-200% more expensive than cotton. However, our survey and longer term fiber demand projections indicate that demand could be 10 to 30 times larger[18] if cottonized flax fibers can be made more consistent in physical properties; if prices could be more stable and if prices could drop below that of cotton[19]. This section will briefly describe some of the existing and newly developing technologies to cottonized flax, review some of the cost information presented in Chapter 2, combine it with other cost information on the raw fiber production side and then look at the likely potential for new cottonizing technologies to give a significant price drop.

3.3.1 The Costs of Existing Mechanical Cottonizing Systems

The three most important costs a producer of cottonized flax faces are:

1) raw material costs;

2) processing costs; and

3) the "waste factor".

All of the costs are very much related. For instance, when flax fibers are mechanically cottonized, (and, to date, this is, by far, the most common way to cottonize flax fibers), a cheap raw material (i.e., the lowest priced flax tows) have either a high percentage of tightly glued together flax bundles or a high percentage of short fine fibers. In either case, the waste factor will be very high (e.g., 40-80%) and hence the final cost of the cottonized flax will be high, especially if the waste cannot be sold (e.g., to paper makers) at a reasonable price. Conversely, if high quality tow is purchased, the waste factor will be relatively low since most of the fiber bundles would be relatively well-retted and hence can be split into single fibers with relatively little dust or unopened fiber bundles. However, in this case the cost of the cottonized flax will also be relatively high, not because of the high waste factor but rather because of the high cost of the raw material.

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[18] See both Chapters 2 and 4 for information that supports this statement

[19] This is assuming that cottonized flax will always be more difficult to spin than cotton because it is less "twisty" than cotton. This may, in fact, be cancelled out if consumers are willing to pay more for the extra comfort they will get from cottonized flax compared to cotton and/or if spinning machine manufacturers find improved ways to spin cottonized flax at little or no additional cost.

In cottonization of flax, 10% - 20% of the processing cost is associated with regularizing the length of the fibers (i.e., trying to reduce the dispersion of fiber lengths). The remaining 80% - 90% of the processing cost is associated with splitting the fiber bundles apart. Mechanical cottonizing systems rely on the mechanical action of very closely set pins, saw teeth and/or breaker plates (e.g., some settings vary by only 2/1000th of an inch) to catch and tear fibers off the fiber bundles. Waste is created when fibers bundles of different sizes and lengths do not physically line up perfectly with the gaps between the various teeth, pins and/or plates. Although they do not line up perfectly, most of the fibers from well retted flax bundles will be stripped off successfully. However, fibers from over-retted or under-retted flax bundles will either be broken into many pieces (i.e., turned into dust) or will remain stubbornly attached to some or all the other fibers in the bundle (i.e., turned into thinner but still very stiff fiber bundles that cannot easily be spun except possible at a low blend rate in a coarse novelty yarn).

Hence, it appears that conventional mechanical flax cottonizers must rely on purchases of well-retted flax fiber for them to be viable. At the present time, almost all such flax fiber is being produced as a by-product of long line flax fiber production and prices for better quality tow needed by cottonizers is in the range of US$500-1,800/tonne depending on the demand and availability of higher quality tows. Table 3.3.1 shows how raw fiber price and the cottonized yield rate (i.e., the non-waste factor) affect the raw material cost to produce one tonne of cottonized fiber. Flax cottonizers are somewhat reluctant to divulge their actual cost of processing but there is a general consensus that it is between US$400-700 per tonne of cottonized fiber. We know that processing costs will vary depending on the initial costs of machinery, the annual throughput, the quality or raw material being used, labor and management costs, the actual cottonizing system being used and so on. We also know that more expensive tows tend to have more consistent, stronger and finer fibers, all of which allow more throughput per hour from cottonizing machinery and hence reduce processing costs. Processing costs are higher for poor grades of tow because more waste material must be handled, stored and disposed of. With this is mind, we will assume the processing charge will vary between US$400-700 depending on the quality of tow (and hence the cottonized yield). This range of costs relative to the quality of the tow that is used (and hence the yield of cottonized flax) is shown in Table 3.3.2.

When we add the calculated raw material costs from Table 3.3.1 with the estimated processing costs shown in Table 3.3.2 we have an estimate of the cost of production, not including marketing costs and return to management and ownership. This is shown in Table 3.3.3.

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Table 3.3.1 – Calculated effect of raw material costs and yield of cottonized flax on the cost (US$/tonne) to produce one tonne of cottonized flax

	Yield of Cottonized Fiber							
Tow Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	1000	667	500	400	333	286	250	222
300	1500	1000	750	600	500	429	375	333
400	2000	1333	1000	800	667	571	500	444
500	2500	1667	1250	1000	833	714	625	556
600	3000	2000	1500	1200	1000	857	750	667
700	3500	2333	1750	1400	1167	1000	875	778
800	4000	2667	2000	1600	1333	1143	1000	889
900	4500	3000	2250	1800	1500	1286	1125	1000

▨ = most common situations

Table 3.3.2 – Estimated relationship between processing cost (US$/tonne) and yield of cottonized flax

	Yield of Cottonized Fiber							
Processing Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	700	700	650	600	600	550	500	500
300	700	700	650	600	600	550	500	500
400	650	650	600	550	550	500	500	500
500	600	600	600	550	500	500	500	500
600	550	550	550	500	500	450	450	450
700	500	500	450	450	400	400	400	400
800	450	400	400	400	400	400	400	400
900	400	400	400	400	400	400	400	400

▨ = most common situations

Table 3.3.3 – Combined effects of raw material and processing costs (US$/tonne) to produce one tonne of cottonized flax

	Yield of Cottonized Fiber							
Tow Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	1700	1367	1150	1000	933	836	750	722
300	2750	1700	1400	1150	1100	979	875	833
400	2650	1983	1600	1350	1217	1071	1000	944
500	3100	2267	1850	1550	1333	1214	1125	1056
600	3550	2550	2050	1700	1500	1307	1200	1117
700	4000	2833	2200	1850	1567	1400	1275	1178
800	4450	3067	2400	2000	1733	1543	1400	1289
900	4900	3400	2650	2200	1900	1686	1525	1400

▨ = most common situations

Table 3.3.1 – Calculated effect of raw material costs and yield of cottonized flax on the cost (US$/tonne) to produce one tonne of cottonized flax

	Yield of Cottonized Fiber							
Tow Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	1000	667	500	400	333	286	250	222
300	1500	1000	750	600	500	429	375	333
400	2000	1333	1000	800	667	571	500	444
500	2500	1667	1250	1000	833	714	625	556
600	3000	2000	1500	1200	1000	857	750	667
700	3500	2333	1750	1400	1167	1000	875	778
800	4000	2667	2000	1600	1333	1143	1000	889
900	4500	3000	2250	1800	1500	1286	1125	1000

▨ = most common situations

Table 3.3.2 – Estimated relationship between processing cost (US$/tonne) and yield of cottonized flax

	Yield of Cottonized Fiber							
Processing Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	700	700	650	600	600	550	500	500
300	700	700	650	600	600	550	500	500
400	650	650	600	550	550	500	500	500
500	600	600	600	550	500	500	500	500
600	550	550	550	500	500	450	450	450
700	500	500	450	450	400	400	400	400
800	450	400	400	400	400	400	400	400
900	400	400	400	400	400	400	400	400

▨ = most common situations

Table 3.3.3 – Combined effects of raw material and processing costs (US$/tonne) to produce one tonne of cottonized flax

	Yield of Cottonized Fiber							
Tow Cost US$/t	20%	30%	40%	50%	60%	70%	80%	90%
200	1700	1367	1150	1000	933	836	750	722
300	2750	1700	1400	1150	1100	979	875	833
400	2650	1983	1600	1350	1217	1071	1000	944
500	3100	2267	1850	1550	1333	1214	1125	1056
600	3550	2550	2050	1700	1500	1307	1200	1117
700	4000	2833	2200	1850	1567	1400	1275	1178
800	4450	3067	2400	2000	1733	1543	1400	1289
900	4900	3400	2650	2200	1900	1686	1525	1400

▨ = most common situations

In all three of the previous tables we have used shading to indicate the most common combinations used to produce medium quality cottonized flax. When we look to the left and below the shaded areas, we can see that high priced tow with a low yield produces cost combinations that are relatively high. However, such combinations are used at present by cottonizers who sell to spinners that want to make fine yarn and/or want a high percentage of cottonized fiber in the final product. In such cases, cottonizers usually get the fineness and consistency they need by buying the best quality tows and then selling their best grade of cottonized flax for $2,500 - 4,000/t. Unfortunately at such price points, the market demand is very limited since the fabrics thus produced can only be sold in very high end markets (in comparison, cotton fibers generally sell in the range of $1,100 – 2,000/t with the ten year average being US$1,550).

The reader might naturally ask why cottonizers do not use combinations shown to the right and above the shaded areas since the total cost of these combinations would generally appear to be cheaper than those in the shaded areas. There are at least two reasons why this is so. The first is that the cottonized process must accomplish three objectives:

1) shorten the fibers;
2) regularize fiber length; and
3) regularize fiber and/or fiber bundle diameters.

Since regularization of fiber length can easily result in a 10-15% yield loss, a 90% yield is almost never experienced even when the highest priced tows are used. Low priced tows are normally low priced because:

1) the shive content is very high;
2) the fiber is very coarse and/or under-retted (i.e., mostly fiber bundles);
3) the fiber is very weak (e.g., over-retted); and/or
4) the fiber is very inconsistent with an undesirable mixture of coarse fibers, weak fibers and/or shives.

This, in turn, means that low priced tows have unacceptably low yields and/or unacceptably coarse fibers when processed on traditional mechanical cottonizing systems. Thus it would seem that cottonized flax will continue to be expensive relative to cotton unless higher quality tows are available at lower prices and/or new technologies are developed which reduce the waste produced during the cottonizing process.

3.3.2 The Development of New Cottonizing Technologies

Much of the new research being done in the area of cottonization is being done in the area of trying to find cheaper alternative means to process lower priced tows so that effective yield is increased. More than anything, this means finding a way or ways to cheaply improve the fineness and consistency of cottonized fibers from the poorer grades of tow. Thus research, in different parts of the world is being done using modified retting techniques, caustic chemicals, enzymes, steam explosion and ultra-sound. All of these systems have produced fine fibers from low quality tow but, to date, none have been used profitably in a commercial scale setting. This should change as further research is carried out and/or costs of the technology are reduced. Basic challenges with each technology are summarized in the following section.

Modified Retting Techniques

Although not thought of generally as a way to improve the cottonization yield, retting has been modified in the past to increase the fineness of the retted fibers. Since cottonized fiber yield generally increases as fiber fineness increases, (provided fibers do not become too weak) any retting technique that improves fineness would generally improve the cottonized fiber yield. These include:

a) double water retting (i.e., retting, drying and then re-retting for an additional short period of time before drying again);

b) turning pulled flax one or more times in the field;

c) field retting flax in as thin a layer as possible, and

d) pulling and/or cutting flax stems when still partly green instead of waiting for the seed to become fully mature.

Caustic Chemicals

Such chemicals are cheap but their effects are difficult to control and many of the resultant fibers are too weak for further processing into staple length fibers, this process is generally only used to produce fibers for use in paper and non-woven textiles. In countries with strong environmental laws, caustic chemicals must be treated and/or be recycled. Such recovery and recycling facilities can add considerably to the total cost of fiber treatment. Since caustic chemicals are relatively cheap, they are often used to treat flax fiber mixtures that have a high shive content.

Enzymes

When micro-organisms grow on flax straw they release enzymes that assist in the breakdown of the pectins and lignins that hold the fibers to the rest of the stem. Researchers have shown that it generally takes only two enzymes to effectively release fiber bundles and fibers from the rest of the straw. When straw is treated with expensive pure forms of these enzymes, the resultant fibers are generally very fine and consistent. However, in the past, when such treatments were scaled up and cheaper commercial enzymes preparations used, the resultant fiber were inconsistent because the cheaper commercial enzymes were not pure enough (i.e., they contained other enzymes which broke down cellulose in the fibers). If pure forms of the enzymes were used, the costs were too high for the process to be profitable. Recent research has shown that the addition of chelating agents can dramatically reduce the amount of enzyme that is needed[20]. In addition, the technology to produce pure enzymes is rapidly improving and consequently enzyme costs are dropping. These are promising developments, however, to the author's knowledge, no one has yet designed the large scale mechanical retting and drying system that would have to be used with an enzyme treatment system. Enzymes have the potential to produce very homogeneous fibers because they will only break-down the non-cellulose (i.e., non bast fiber) portion of the stem, regardless of initial bundle size.

Enzyme retting systems require some method of applying enzymes and chelating agents to clean fiber and/or straw, and a method to rinse and dry the fibers before putting them through a modified cotton carding system. Cottonized fiber yields should be greater than 80%.

Steam Explosion

Research into steam explosion (i.e., flash hydrolysis) of bast fibers has taken place for almost two decades. Steam explosion is based on the principle that pectins and lignins absorb more moisture than cellulose. Clean fibers are placed in a pressure vessel with steam and roughly 0.5% NaOH for roughly 15 minutes at 45 p.s.i. after which time the pressure is rapidly released. Since more water, in the form of steam, is held by the pectins and lignins than by the cellulose, the rapid drop in pressure causes the pressured steam to "explode" at a relatively faster rate from the pectins and lignins. Thus the fiber bundles that have the most pectins and lignins expand with the greatest force, whereas single fibers with no pectin or lignin hardly expand. The steam also softens the pectins and lignins. Immediately after pressure release, the damaged fiber mass is forced by air or hot water through a narrow opening which forces the fibers to rub against each other and hence to further loosen the pectins and lignins attached to the fiber. The fiber mass is then rinsed with hot water which semi-dissolves the pectins and lignins and carries them away from the fibers. The fibers are then dried and passed through a modified cotton carding machine to regularize the fiber lengths. The resultant fibers are very spinnable since steam explosion is a very effective way of homogenizing bast fibers because it tends to turn all fiber bundles, regardless of initial size, into single fibers.

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[20] Much of the most recent work on enzyme treatments has been done by Danny Akin and his associates at the USDA Russell Research Center in Athens, Georgia.

Steam explosion requires, at the minimum, a source of steam, one or more pressure vessels, a way to treat and/or recycle rinse water containing pectins and lignins, a fiber drying system and a modified cotton carding system. The first three requirements require relatively high initial capital costs, a source of good water, and much more design complexity than does mechanical cottonization. In the past, this has discouraged the construction of commercial-scale steam explosion systems for cottonizing flax. Estimated costs for steam explosion vary from US$300 to 1,200 per tonne of cottonized fiber with the lowest costs being associated with locations that already have access to steam and fiber drying and cleaning equipment. New research is continuing to be carried out with the goal of further reductions in processing costs and initial theoretical results look very promising. Cottonized fiber yields should be greater than 80% when steam explosion is used.

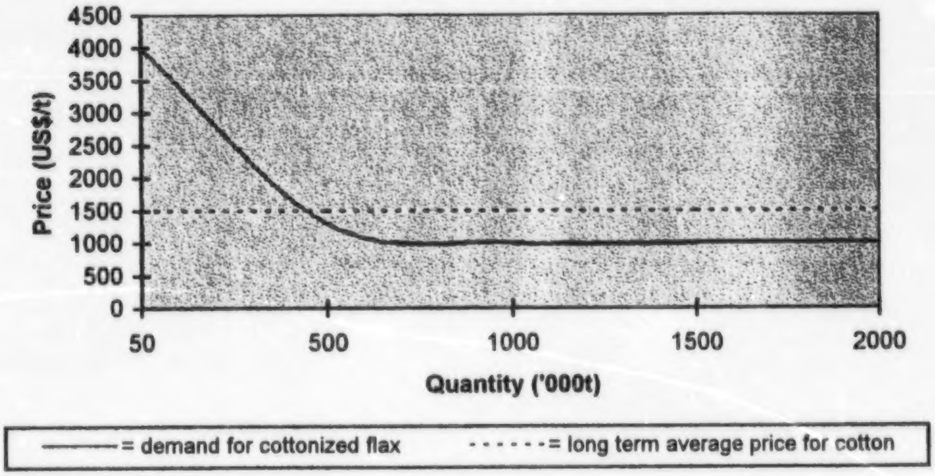
Ultra-Sound

Research into the application of ultra-sound waves to break down bast fibers is relatively new and is based on the principle that, under the right conditions, items made up of a composite of materials can be made to partly or totally separate because different materials will vibrate at different speeds when exposed to ultrasonic waves for a prolonged period of time. Laboratory trials have shown that flax can be separated into single fibers by submerging the bundles under water and exposing them to certain frequencies and duration of ultrasonic waves. The resultant fibers appear to be very spinnable. Such a system would require a ultrasonic wave generator, tanks of water, a way to treat and/or recycle rinse water containing pectins and lignins, a fiber drying system and a modified cotton carding system. To the author's knowledge, research into the use of ultra-sound is still at a pre-commercialization stage and no commercial scale operations are in operation.

3.3.3 Future Potential

There is no doubt that all of the above five techniques (and more especially the last four) have the potential to decrease processing costs and/or improve the yield of cottonized fibers. As time goes on and R&D is carried out in each of these technologies, the cost of processing will be reduced. How much will quantity demanded increase if costs can be reduced and/or how much will costs have to be squeezed before a significant increase in demand can be expected? We can now refer back to the theoretical long term demand curve for cottonized flax that was developed in Chapter 2.

Figure 3-5 - Theoretical long term demand curve for cottonized flax



NOTES:

1) *Over the last 20 years, the USA cotton price has averaged about US$0.70/lb or US$1,550/t.*
2) *Cottonized flax prices at present vary from 10% to 200% more than cotton prices depending on the season and whether it is in fashion as a novelty fiber or not. Present world consumption is less than 100,000 tonnes annually with an average price of about US$1.1.0/lb or US$2,425/t (prices range from US$1,200 – 4,000/t)*
3) *Total world cotton consumption is roughly 20 million tonnes and is growing by about 200,000 tonnes annually (i.e., 1%/yr)*
4) *Several spinners and fiber brokers have stated the use of cottonized flax could double or triple if it was not more than 25% higher than the cotton price (i.e., 125% of US$1,550 or roughly US$1,900/t) even though it would still be considered a novelty fiber used to compliment commodity fibers like cotton and polyester.*
5) *If spinners could buy cottonized flax for half the price of cotton (i.e., 50% of US$1,550 or US$775), cottonized flax would become a substitute for cotton in many end uses in many countries and could easily replace 10% of the worldwide cotton market.*

If we assume Figure 3.3.1 represents the reasonable long term potential market demand for cottonized flax we can then determine by how much raw material and processing costs must be reduced before usage of cottonized flax will significantly rise. To do this we can calculate backwards from a target selling price of US$1,900/t which is the target price that would double cottonized flax

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fiber demand, providing fiber consistency can be improved over that presently produced by mechanical cottonizing systems. It is common for niche or novelty fiber producers to have gross margins of at least 30% above raw material and processing costs since volumes can vary greatly from year to year. Commodity fiber producers, on the other hand, are more likely to have gross margins of 5-15%. If we take off a gross margin of 30% we are left with a production cost target price of US$1,330/t to double cottonized flax usage, and if we take off a gross margin of 15% from a target price of US$775/t we are left with a production cost target price of roughly US$660/t. Assume that enzymes, steam explosion or ultra sound are used and hence that the yield of cottonized flax fiber is at least 70% (NOTE: we could spend about 9% more on processing if our yield of cottonized fiber was 80%)

Table 3.3.4 - Maximum costs (US$/t) that can be incurred with new technologies to cottonize flax

A	B	C	D
100	143	1187	517
200	286	1044	**374**
300	429	901	**231**
400	571	759	89
500	714	616	(54)
600	857	473	(197)
700	1000	330	(340)
800	1143	187	(483)
900	1286	44	(626)

= most likely range of costs

Column A = tow price in US$/t

Column B = raw material cost in US$/t at 70% cottonized fiber yield to produce one tonne of cottonized flax

Column C = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$1,330 (i.e., 1330 - Col B)

Column D = maximum amount that could be spent on processing to generate a total raw material and processing charge of US$660 (i.e., 660 – Col B.)

Now consider the results shown in Table 3.3.4. Under the scenario shown by Column C (i.e., doubling the demand for cottonized flax by pricing it at no more than 25% higher than the cotton price), we can see that we could spend from US$44 to $1,187 on processing per tonne of cottonized fiber, depending on raw material costs. With the three new technologies mentioned above, we would have to use relatively clean tow but not finely divided tow since these new technologies appear to be particularly good at dividing fiber bundles to produce more homogeneous lots of fiber.

This means, at the high end of acceptable prices (i.e., Column C), if processing costs were as low as US$187/t a cottonizer could pay as much as US$800/t for tow and, at the low end, if processing costs were as high as US$759/t a processor fiber demand, providing fiber consistency can be improved over that presently produced by mechanical cottonizing systems. It is common for niche or novelty fiber producers to have gross margins of at least 30% above raw material and processing costs since volumes can vary greatly from year to year. Commodity fiber producers, on the other hand, are more likely to have gross margins of 5-15%. If we take off a gross margin of 30% we are left with a production cost target price of US$1,330/t to double cottonized flax usage, and if we take off a gross margin of 15% from a target price of US$775/t we are left with a production cost target price of roughly US$660/t. Assume that enzymes, steam explosion or ultra sound are used and hence that the yield of cottonized flax fiber is at least 70% (NOTE: we could spend about 9% more on processing if our yield of cottonized fiber was 80%)

Table 3.3.4 - Maximum costs (US$/t) that can be incurred with new technologies to cottonize flax

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▨ = most likely range of costs

Column A = tow price in US$/t

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Column C = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$1,330 (i.e., 1330 - Col B)

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Now consider the results shown in Table 3.3.4. Under the scenario shown by Column C (i.e., doubling the demand for cottonized flax by pricing it at no more than 25% higher than the cotton price), we can see that we could spend from US$44 to $1,187 on processing per tonne of cottonized fiber, depending on raw material costs. With the three new technologies mentioned above, we would have to use relatively clean tow but not finely divided tow since these new technologies appear to be particularly good at dividing fiber bundles to produce more homogeneous lots of fiber.

This means, at the high end of acceptable prices (i.e., Column C), if processing costs were as low as US$187/t a cottonizer could pay as much as US$800/t for tow and, at the low end, if processing costs were as high as US$759/t a processor could not pay more than US$400/t of tow. It is highly unlikely processing costs would be as high as US$759/t since this is the upper end of processing costs when existing mechanical cottonizing systems are used. Thus, in the future, cottonizers using non-mechanical cottonizing systems should be able to pay US$400-800/t[21] of tow; make a 30% gross margin and still be able to double the demand worldwide for cottonized flax by selling for not more than 25% higher than the average, long term cotton price. Such a scenario would use an additional 100-130,000 tonnes of flax tow per year. In the context of flax fiber produced from linseed flax, in Western Canada, this volume of tow would represent roughly half of all the flax straw presently produced[22].

We should also consider the likelihood of producing cottonized flax that is not more than half the price of cotton. In this case processing costs would have to be in between US$231 and US$374 to allow a cottonizer to pay US$200-300/tonne for tow. To minimize freight charges such tow would have to be cottonized near the source of tow. This is, in a way, an extremely low target price since it is likely that manufacturers of spinning machinery would modify cotton spinning systems slightly to more efficiently spin cottonized flax if they perceived that the price of cottonized flax would remain relatively low. As volumes increased, costs of processing and using cottonized flax would also fall as people learned to be more cost effective.

Could farmers produce reasonably clean tow for US$200-$300/tonne? First of all let us convert the US$ figures shown in Table 3.3.4 into Canadian dollars so that it will be easier for readers to understand the implications at the Saskatchewan farm process level. For this purpose we conservatively used an exchange rate of C$1.00=US$0.75 (in June, 2000 it was C$1.00=US$0.68). The following tables show how clean tow prices would vary under several combinations of collection costs, processing costs, yields of tow and farmers incentives.

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[21] Keep in mind that this is based on an effective cottonized yield of 70%; ability to pay more for raw material would rise about 9% if the effective cottonized yield could be raised to 80%

[22] Based on the assumptions of 2.0 million acres with 0.5 tonnes of residual straw at 20% fiber, we get a total fiber potential of 200,000 tonnes. In reality, however, this figure is likely to be considerably less because many flax fields are too far apart to allow cost effective collection of the straw.

Table 3.3.5 - Maximum cost (C$/t) that can be incurred with new technologies to cottonize flax

A	B	C	D
133	191	1,583	689
267	381	1,392	232
400	572	1,201	308
533	761	1,012	119
667	952	821	(72)
800	1,143	631	(263)
933	1,333	440	(453)
1,067	1,524	249	(644)
1,200	1,715	59	(835)

A = tow price in C$
B = raw material cost in C$ at 70% cottonized fiber yield to produce one tonne of cottonized flax
C = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$1,330 (i.e., 1,330 - B)(i.e., C$1,773-B)
D = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$660 (i.e., 660 - B)(i.e., C$880-B)

The shaded rectangles show the amounts flax cottonizers could theoretically afford to pay for tow given a range of cottonizing processing costs and still generate a total cost low enough to allow a final selling price of US$1,330 or US$660[23].

Existing mechanical cottonizers buy fiber that is relatively free of shives (i.e., <5% shives). Some or all of the newer cottonizing technologies may not need fiber which is this clean but to be conservative we will assume that the same level of cleanliness is required. How much does it cost to clean fiber suitable for cottonizing? In Europe the fiber is already roughly cleaned during the process of making long line. Even so, it is commonly claimed to cost US$150/t to clean tow. Actual costs may be considerably lower depending on age of equipment, type of equipment, skill of operators, shive content of raw material going in, desired shive content of clean fiber, etc. Private tow cleaners are reluctant to reveal their true costs for fear of encouraging new entrants into the industry.

To get around this problem we have made up a pro forma budget based on new equipment from the Charle Company that can be bought in Western Europe at this time. This equipment is relatively expensive and has a low throughput per hour. It is, however, reliable and components of this system are very common in Western European flax processing plants. The results of this exercise are shown in Table 3.3.6. It shows calculated cost of cleaning tow of $173 for one shift and $135 for two shifts. Some in the tow cleaning industry could argue that the costs

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[23] Keep in mind this assumes only a 70% yield of cottonized flax and a 30% selling margin for the lower volume US$1,330/t priced fiber and a 15% selling margin for the potentially higher volume US$660/t priced fiber.

Table 3.3.5 - Maximum cost (C$/t) that can be incurred with new technologies to cottonize flax

A	B	C	D
133	191	1,583	689
267	381	1,392	232
400	572	1,201	308
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1,200	1,715	59	(835)

A = tow price in C$
B = raw material cost in C$ at 70% cottonized fiber yield to produce one tonne of cottonized flax
C = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$1,330 (i.e., 1,330 - B)(i.e., C$1,773-B)
D = maximum amount that could be spent in processing to generate a total raw material and processing charge of US$660 (i.e., 660 - B)(i.e., C$880-B)

The shaded rectangles show the amounts flax cottonizers could theoretically afford to pay for tow given a range of cottonizing processing costs and still generate a total cost low enough to allow a final selling price of US$1,330 or US$660[23].

Existing mechanical cottonizers buy fiber that is relatively free of shives (i.e., <5% shives). Some or all of the newer cottonizing technologies may not need fiber which is this clean but to be conservative we will assume that the same level of cleanliness is required. How much does it cost to clean fiber suitable for cottonizing? In Europe the fiber is already roughly cleaned during the process of making long line. Even so, it is commonly claimed to cost US$150/t to clean tow. Actual costs may be considerably lower depending on age of equipment, type of equipment, skill of operators, shive content of raw material going in, desired shive content of clean fiber, etc. Private tow cleaners are reluctant to reveal their true costs for fear of encouraging new entrants into the industry.

To get around this problem we have made up a pro forma budget based on new equipment from the Charle Company that can be bought in Western Europe at this time. This equipment is relatively expensive and has a low throughput per hour. It is, however, reliable and components of this system are very common in Western European flax processing plants. The results of this exercise are shown in Table 3.3.6. It shows calculated cost of cleaning tow of $173 for one shift and $135 for two shifts. Some in the tow cleaning industry could argue that the costs

---

[23] **Keep in mind this assumes only a 70% yield of cottonized flax and a 30% selling margin for the lower volume US$1,330/t priced fiber and a 15% selling margin for the potentially higher volume US$660/t priced fiber.**

4

are much lower than this level but none are likely to argue that costs are higher. To make the costs easier to work with we rounded the two shift cost up to $140 per tonne of clean fiber. We then calculated some scenarios based on these costs and also on a cost 50% lower (i.e., $70/t) so that the actual range of costs that tow cleaners have experienced should be covered within this range.

Once this was done we made up a series of scenarios and sensitivity analysis tables (See Table 3.3.7) to find out under what conditions it would be possible for clean tow to be sold at a price that would be no more than the maximum cost (C$) that could be incurred to sell cottonized flax at the higher target price of US$1,330 and the lower target price of $660.

First consider the lower volume, higher target cost of US$1,330. According to Table 3.3.5, the maximum price cottonizers could pay under such a scenario would rnage from C$800 to 1,067 depending on their cost of cottonizing. With this range in mind, we can see from Table 3.3.8 that it should be profitable to supply clean tow at almost all combinations of collection costs, yields of tow and cleaning cost with the exception of paying $80/tonne of straw and getting only 15-20% yield of clean tow from that straw. This is indicated in Table 3.3.8.

Now consider the higher volume, lower target, cost of US$660/tonne for cottonized flax. According to Table 3.3.5, the maximum price cottonizers could pay under this scenario for clean tow would range from C$267 to C$400, depending on their cost of cottonizing. Given this range of possibility we can see from Table 3.3.8 that there are considerably fewer combinations of collection costs, yields of tow and cleaning costs that would allow profits to be made supplying clean tow to cottonize. The possible combinations are shown in Table 3.3.9.

Table 3.3.6 - Pro forma cost of tow cleaning

Assumptions:

All costs in Canadian $

All equipment purchased new with sets of breaker rollers in front of a Charle 4-drum cleaning system

	One Shift	Two Shifts
Capital Costs:		
Bale Opener	100,000	100,000
Breaker rollers	150,000	150,000
Charle 4-drum system	400,000	400,000
Electrical system	100,000	100,000
Dust collection system	150,000	150,000
Building	300,000	300,000
Misc.	50,000	50,000
Total	*1,250,000*	*1,250,000*
Expected life in years	20	20
Salvage value	10%	10%
Depreciation per year	*56,250*	*56,250*
Opportunity cost of capital	9%	9%
Charge for capital	*61,875*	*61,875*
Insurance premiums	0.5%	0.5%
Insurance/year	*6,250*	*6,250*
Total Fixed Costs	**124,375**	**124,375**
Operating Costs:		
Shifts in 24 hours	1	2
Length of shift in hours	8	8
Number of working days/month	22	22
Number of technicians/shift	2	2
Number of supervisors/shift	1	1
Salary per hour of technicians	12	12
Salary per hour of supervisor	16	16
Technicians' salaries/year	50,688	101,376
Supervisors' salary/year	33,792	67,584
Total salaries	*84,480*	*168,960*
Electricity cost per hour	10	10
Electricity cost/year	*21,120*	*42,240*
Heat & drying cost per hour	10	10
Heat & drying cost/year	*21,120*	*31,680*
Repairs & Maintenance rate	5%	5%
Repairs & Maintenance/year	*62,500*	*93,750*
Tonnes of dirty tow processed per hour	1.50	1.50
Shive content of dirty tow	30%	30%
Tonnes of dirty tow processed/year	3,168	6,336
Value of tonne of dirty tow for inventory	400	400
Insurance rate on tow	1%	1%
Insurance premiums on tow	*12,672*	*25,344*
Months material in storage	*6*	*6*
Charge for capital invested in tow (6 months)	*57,024*	*114,048*
Total Operating Costs	**258,916**	**476,022**
Total Fixed & Operating Costs	**383,291**	**600,397**
Clean (<5% shive) tow produced per hour	1.05	1.05
Tonnes of clean tow/year	2,218	4,435
Per Tonne cost of processing tow	**173**	**135**

Table 3.3.7 - Minimum selling prices of tow under different scenarios

- when farmer incentive is $5/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	506	583	659
	20%	420	477	535
	25%	368	414	460
	30%	334	372	410
	40%	290	319	348
	50%	265	288	311

- when farmer incentive is $5/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	426	502	579
	20%	339	397	454
	25%	288	334	380
	30%	253	291	330
	40%	210	239	267
	50%	184	207	230

- when farmer incentive is $10/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	544	621	698
	20%	449	506	564
	25%	391	437	483
	30%	353	391	429
	40%	305	334	362
	50%	276	299	322

- when farmer incentive is $10/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	464	541	617
	20%	368	426	483
	25%	311	357	403
	30%	272	311	349
	40%	224	253	282
	50%	196	219	242

- when farmer incentive is $20/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	621	698	774
	20%	506	564	621
	25%	437	483	529
	30%	391	429	468
	40%	334	362	391
	50%	299	322	345

- when farmer incentive is $20/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	541	617	694
	20%	426	483	541
	25%	357	403	449
	30%	311	349	387
	40%	253	282	311
	50%	219	242	265

- when farmer incentive is $40/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	774	851	928
	20%	621	679	736
	25%	529	575	621
	30%	468	506	544
	40%	391	420	449
	50%	345	368	391

- when farmer incentive is $40/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	694	771	847
	20%	541	598	656
	25%	449	495	541
	30%	387	426	464
	40%	311	339	368
	50%	265	288	311

- when farmer incentive is $80/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,081	1,158	1,234
	20%	851	909	966
	25%	713	759	805
	30%	621	659	698
	40%	506	535	564
	50%	437	460	483

- when farmer incentive is $80/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,001	1,077	1,154
	20%	771	828	886
	25%	633	679	725
	30%	541	579	617
	40%	426	454	483
	50%	357	380	403

NOTE: all costs are in Canadian dollars unless shown otherwise.

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Table 3.3.8 - Acceptable selling prices of tow for target cost of US$1,330

- when farmer incentive is $5/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	506	583	659
	20%	420	477	535
	25%	368	414	460
	30%	334	372	410
	40%	290	319	348
	50%	265	288	311

- when farmer incentive is $5/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	426	502	579
	20%	339	397	454
	25%	288	334	380
	30%	253	291	330
	40%	210	239	267
	50%	184	207	230

- when farmer incentive is $10/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	544	621	698
	20%	449	506	564
	25%	391	437	483
	30%	353	391	429
	40%	305	334	362
	50%	276	299	322

- when farmer incentive is $10/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	464	541	617
	20%	368	426	483
	25%	311	357	403
	30%	272	311	349
	40%	224	253	282
	50%	196	219	242

- when farmer incentive is $20/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	621	698	774
	20%	506	564	621
	25%	437	483	529
	30%	391	429	468
	40%	334	362	391
	50%	299	322	345

- when farmer incentive is $20/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	541	617	694
	20%	426	483	541
	25%	357	403	449
	30%	311	349	387
	40%	253	282	311
	50%	219	242	265

- when farmer incentive is $40/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	774	851	928
	20%	621	679	736
	25%	529	575	621
	30%	468	506	544
	40%	391	420	449
	50%	345	368	391

- when farmer incentive is $40/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	694	771	847
	20%	541	598	656
	25%	449	495	541
	30%	387	426	464
	40%	311	339	368
	50%	265	288	311

- when farmer incentive is $80/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,081	1,158	1,234
	20%	851	909	966
	25%	713	759	805
	30%	621	659	698
	40%	506	535	564
	50%	437	460	483

- when farmer incentive is $80/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,001	1,077	1,154
	20%	771	828	886
	25%	633	679	725
	30%	541	579	617
	40%	426	454	483
	50%	357	380	403

▨ = acceptable selling prices of tow for target cost of US$1,330 for cottonized flax produced new technology

NOTE: all costs are in Canadian dollars unless shown

Table 3.3.9 - Acceptable selling prices of tow for target cost of US$660

- when farmer incentive is $5/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	506	583	659
	20%	420	477	535
	25%	368	414	460
	30%	334	372	410
	40%	290	319	348
	50%	265	288	311

- when farmer incentive is $5/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	426	502	579
	20%	339	397	454
	25%	288	334	380
	30%	253	291	330
	40%	210	239	267
	50%	184	207	230

- when farmer incentive is $10/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	544	621	698
	20%	449	506	564
	25%	[illegible]	437	483
	30%	353	391	429
	40%	305	334	[illegible]
	50%	276	299	[illegible]

- when farmer incentive is $10/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	464	541	617
	20%	368	426	483
	25%	311	357	403
	30%	272	[illegible]	[illegible]
	40%	224	253	[illegible]
	50%	196	219	[illegible]

- when farmer incentive is $20/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	621	698	774
	20%	506	564	621
	25%	437	483	529
	30%	391	429	468
	40%	334	362	[illegible]
	50%	299	322	[illegible]

- when farmer incentive is $20/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	541	617	694
	20%	426	483	541
	25%	357	403	449
	30%	311	[illegible]	387
	40%	253	282	[illegible]
	50%	219	242	[illegible]

- when farmer incentive is $40/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	774	851	928
	20%	621	679	736
	25%	529	575	621
	30%	468	506	544
	40%	[illegible]	420	449
	50%	345	368	[illegible]

- when farmer incentive is $40/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	694	771	847
	20%	541	598	656
	25%	449	495	541
	30%	387	426	464
	40%	311	[illegible]	[illegible]
	50%	265	288	[illegible]

- when farmer incentive is $80/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,081	1,158	1,234
	20%	851	909	966
	25%	713	759	805
	30%	621	659	698
	40%	506	535	564
	50%	437	460	483

- when farmer incentive is $80/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,001	1,077	1,154
	20%	771	828	886
	25%	633	679	725
	30%	541	579	617
	40%	426	454	483
	50%	[illegible]	380	403

■ = acceptable selling prices of tow for target cost of US$660 for cottonized flax produced with new tech

NOTE: all costs are in Canadian dollars unless shown otherwise.

Table 3.3.8 - Acceptable selling prices of tow for target cost of US$1,330

- when farmer incentive is $5/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	506	583	659
	20%	420	477	535
	25%	368	414	460
	30%	334	372	410
	40%	290	319	348
	50%	265	288	311

- when farmer incentive is $5/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	426	502	579
	20%	339	397	454
	25%	288	334	380
	30%	253	291	330
	40%	210	239	267
	50%	184	207	230

- when farmer incentive is $10/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	544	621	698
	20%	449	506	564
	25%	391	437	483
	30%	353	391	429
	40%	305	334	362
	50%	276	299	322

- when farmer incentive is $10/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	464	541	617
	20%	368	426	483
	25%	311	357	403
	30%	272	311	349
	40%	224	253	282
	50%	196	219	242

- when farmer incentive is $20/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	621	698	774
	20%	506	564	621
	25%	437	483	529
	30%	391	429	468
	40%	334	362	391
	50%	299	322	345

- when farmer incentive is $20/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	541	617	694
	20%	426	483	541
	25%	357	403	449
	30%	311	349	387
	40%	253	282	311
	50%	219	242	265

- when farmer incentive is $40/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	774	851	928
	20%	621	679	736
	25%	529	575	621
	30%	468	506	544
	40%	391	420	449
	50%	345	368	391

- when farmer incentive is $40/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	694	771	847
	20%	541	598	656
	25%	449	495	541
	30%	387	426	464
	40%	311	339	368
	50%	265	288	311

- when farmer incentive is $80/t;
costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,081	1,158	1,234
	20%	851	909	966
	25%	713	759	805
	30%	621	659	698
	40%	506	535	564
	50%	437	460	483

- when farmer incentive is $80/t;
costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,001	1,077	1,154
	20%	771	828	886
	25%	633	679	725
	30%	541	579	617
	40%	426	454	483
	50%	357	380	403

☐ = acceptable selling prices of tow for target cost of US$1,330 for cottonized flax produced new technology

NOTE: all costs are in Canadian dollars unless shown

Table 3.3.9 - Acceptable selling prices of tow for target cost of US$660

- when farmer incentive is $5/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	506	583	659
	20%	420	477	535
	25%	368	414	460
	30%	334	372	410
	40%	290	319	348
	50%	265	288	311

- when farmer incentive is $5/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	426	502	579
	20%	339	397	454
	25%	288	334	380
	30%	253	291	330
	40%	210	239	267
	50%	184	207	230

- when farmer incentive is $10/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	544	621	698
	20%	449	506	564
	25%	391	437	483
	30%	353	391	429
	40%	305	334	362
	50%	276	299	322

- when farmer incentive is $10/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	464	541	617
	20%	368	426	483
	25%	311	357	403
	30%	272	311	349
	40%	224	253	282
	50%	196	219	242

- when farmer incentive is $20/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	621	698	774
	20%	506	564	621
	25%	437	483	529
	30%	391	429	468
	40%	334	362	391
	50%	299	322	345

- when farmer incentive is $20/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	541	617	694
	20%	426	483	541
	25%	357	403	449
	30%	311	349	387
	40%	253	282	311
	50%	219	242	265

- when farmer incentive is $40/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
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	20%	621	679	736
	25%	529	575	621
	30%	468	506	544
	40%	391	420	449
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- when farmer incentive is $40/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	694	771	847
	20%	541	598	656
	25%	449	495	541
	30%	387	426	464
	40%	311	339	368
	50%	265	288	311

- when farmer incentive is $80/t; Cleaning costs are $140/t

		Collection Costs ($/tonne of straw)		
		40	50	60
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	20%	851	909	966
	25%	713	759	805
	30%	621	659	698
	40%	506	535	564
	50%	437	460	483

- when farmer incentive is $80/t; Cleaning costs are $70/t

		Collection Costs ($/tonne of straw)		
		40	50	60
Yield of Tow	15%	1,001	1,077	1,154
	20%	771	828	886
	25%	633	679	725
	30%	541	579	617
	40%	426	454	483
	50%	357	380	403

▨ = acceptable selling prices of tow for target cost of US$660 for cottonized flax produced with new tech

NOTE: all costs are in Canadian dollars unless shown otherwise

From the results shown in this table we can see that high cleaning costs (i.e., $140/tonne vs. $70/tonne) and high incentives paid to farmers appear to have the most limiting effect on being able to supply tow at such a low price. This is not surprising. We should keep in mind that, with present oilseed and fiber varieties it is unlikely that the yield of tow from oilseed varieties will be greater than 20-30%[24] and fiber varieties from 30-50%. Thus in Tables 3.3.7, 3.3.8, and 3.3.9, the four tops rows of numbers in each scenario matrix could be oilseed flax varieties and the bottom three rows could be fiber varieties. When oilseed flax varieties are grown the farmer incentive payment to save his straw and/or manipulate seeding rates, etc. does not have to be very high since most of the income will come from the seed. However when fiber flax varieties are grown the farmer incentive payment to manipulate the quantity and quality of his straw has to be quite high because most of his income must come from the straw.

Given the above information, the reader can see that if cleaning costs are high (i.e., $140/tonne), oilseed flax with 25% yield of tow and with $10 or less of farmer incentive and collection costs of $40/tonne may give a low enough combination of costs but at this low an incentive, the quality of straw is likely to be quite inconsistent. On the other extreme, an incentive of $80/tonne results in two prices that are too high. An incentive of $40/tonne generates some plausible low cost combinations but $40/tonne for straw is probably not enough incentive to get farmers interested in growing fiber flax unless suitable "dual-purpose" varieties can be found. Thus if cleaning costs are as high as $140/tonne of clean tow it will be very difficult to supply clean tow that will allow cottonizers to meet a lower target cost of US$660.

Now consider the lower cost cleaning assumption of $70/tonne. Under this assumption there are certainly several oilseed combinations that could work if the quality of straw can be consistent enough with a farmer incentive payment of $20/tonne or less. At the $80/tonne incentive for fiber flax straw there are several interesting combinations with low enough costs and quality should be quite consistent with such a high straw incentive. Once again an incentive of $40/tonne generates some plausible low cost combinations but $40/tonne for straw is probably not enough incentive to get farmers interested in growing fiber flax unless suitable "dual-purpose" varieties can be found.

The reader should note that the cost of producing clean tow can be roughly the same whether it is produced from fiber or oilseed varieties (e.g., an oilseed variety with a $5 farmer incentive, cleaning costs of $70, 25% fiber content and $60 collection cost has a clean tow cost of $380/tonne; this is the same clean tow cost as fiber variety with an $80 farmer incentive, 50% cleaning costs of $70, 50% fiber content and $50 collection costs). This, at first, may not seem to make sense since oilseed flax straw is almost "free" from the farmer whereas a relatively large straw incentive would have to be paid to get farmers to grow a fiber crop. There are, however, reasons and circumstances when growing a fiber crop that would make sense.

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[24] Much of this depends on how much shive falls off during combining and/or baling. If no handling of straw is done most oilseed flax varieties will have a fiber content of 10-20%, and fiber varieties from 25-35%.

First of all, the fiber content of many oilseed varieties is naturally quite low and, even after combining and baling the straw, the fiber content in the bale might still be 25%, or less. Baling, loading, transporting, stacking and unstacking costs and processing costs are the same whether a bale has a high or low fiber content. To date, the straw incentive farmers receive is also the same whether the straw has a high or low fiber content. The clean tow from a low fiber content bale will be a smaller quantity than that from a high fiber content bale and hence, on a per unit of weight basis, the low fiber content straw has to bear a proportionately higher cost for straw collecting, processing and farmer incentive costs. Thus if the fiber content is low enough the final cost of producing clean tow can actually be higher than the cost of producing clean tow using high fiber content varieties.

The second reason why it may be advantageous, under certain circumstances, to grow fiber varieties has to do with quality. Flax straw and the resultant fibers can have a wide range of quality parameters depending on the interactive effects of agronomic practices (e.g., which variety, how was it fertilized, etc.) weather and soil conditions and how it was treated mechanically (e.g., combining method, baling method, etc.). There are a variety of end uses for flax and different uses have different quality requirements. For instance, a fiber pot maker may only require that flax fibers be relatively free of shives and have a high percentage of strong fibers that are ten centimeters or less in length. A dry spinner of flax tow for yarns, may, on the other hand, require flax fibers that meet minimum and maximum criteria for length, fineness, strength, color and trash content. In these two examples, the dry spinner will pay a much higher price for flax tow than will the fiber pot maker, providing the flax tow is of suitable higher quality.

Sometimes high quality tow is produced at the same cost as low quality tow but this is almost always due to luck. In most cases, higher quality tow is only possible if more care and attention is paid to the flax straw crop during its growth, harvest and processing. For this to happen, farmers need a financial incentive. The amount of incentive they need is highly correlated to the amount of extra costs they will have to incur (e.g., growing fiber varieties often means that per acre seed costs will be $40 to $90 more than if oilseed varieties are grown). The cost of such incentives must ultimately be paid for from the sale of clean tow or long line fiber, however, if fiber content is slow and/or straw yields per acre are low (e.g., most oilseed varieties) the paying of high farmers incentives could easily result in a final clean fiber cost which is too high for the market place. In such instances it may be essential to grow a high fiber content, high straw yield fiber variety so that the farmers incentive can be high enough to get quality fiber but the unit cost of tow will still be low enough to make it an attractive proposition for everyone in the marketing chain. Thus it is likely that most end-users requiring higher quality flax fiber will require the use of fiber flax varieties.

On the other hand, end-users requiring only lower quality fibers are generally not willing or able to pay the type of price premiums that higher quality flax fibers could command. This, in turn, means that farmer incentives must be kept low and hence that almost all the farmers' revenue must come from selling seed.

As an aid to analyzing this idea further, we have prepared several more tables. The first of these shows the approximate variable costs to grow oilseed flax on stubble in Saskatchewan. To simplify the costing we have assumed all machinery is hired on a custom basis (see Table 3.3.10). Different locations and different costs but it would be reasonable to assume roughly $100/acre for variable costs of flax grown on stubble. Thus any revenue above this amount will be called a "gross margin". The gross margin can then be used to pay for the return to land, labor and capital. We have then prepared two sensitivity scenario matrices showing typical gross margins that might be expected where an oilseed flax crop is grown (Table 3.3.11) and when a fiber flax crop is grown (Table 3.3.12). In both scenarios we have assumed the seed is sold for $7.00/bushel; in the oilseed case we assume the farmer incentive for the straw is $10/tonne and in the oilseed case we assume the farmers incentive for the straw is $80/tonne. F course, in real life, prices at a given time or location could be higher or lower but we have tried to use reasonable seed and straw prices[25]. A higher seed price would, of course make seed production relatively more attractive and a higher straw incentive would make straw production more attractive.

Table 3.3.10 - Approximate variable costs of growing flax

Rate of seeding	40.00	lbs/acre
Cost of purchased seed	10.00	/bushel
Seeding Cost	*7.14*	*$/acre*
Rate of actual N fertilizer	40.00	lbs/acre
Cost of purchased N	0.35	$/lb
Rate of actual P fertilizer	20.00	lbs/acre
Cost of purchased P fertilizer	0.37	$/lb
Fertilizer Cost	*21.40*	*$/acre*
Herbicide Cost	*22.00*	*$/acre*
Crop Insurance	*3.00*	*$/acre*
Custom Machinery Costs	*35.00*	*$/acre*
Labor Cost	*8.00*	*$/acre*
Other	*3.00*	*$/acre*
Total Variable Costs	99.54	$/acre

In Table 3.3.11 we have highlighted the gross margins most likely to be obtained by growers of oilseed flax given our price assumptions. These range from $43 to 118/acre. We then made an assumption that the cost of growing a fiber flax crop could be as high as $100/acre more due to higher costs for seed ($30-50), possible

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[25] Farmers in Quebec who grew fiber flax for long line production are presently getting $150/tonne of straw; European farmers of fiber flax get even more.

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extra field operations ($10-20) and possibly some lost net income from a non-flax crop the following year if the flax is left to ret in the spring of the following year ($30-60). After adding these extra $100/acre of costs to our oilseed production cost estimate of $100/acre we get an approximate variable cost of $200/acre for fiber flax. We then calculated gross margins for growing fiber flax and highlighted the most likely range of gross margins (Table 3.3.12). We can see that, in general, the gross margins from growing fiber flax are somewhat higher than growing oilseed flax but there are certainly some combinations where an oilseed crop could generate a higher gross margin. Critics will say that oilseed flax seed yields and prices could be higher than those shown but based on limited agronomic and processing trials with fiber flax in Saskatchewan, higher straw yields and prices could also be the case. Thus we should continue to look at both oilseed and fiber flax varieties as potential sources of fiber. However, many agronomic, harvesting and processing trials are needed over a multi-year period to better understand and clarify under what fiber and seed demand conditions each should be grown and to what extent straw yields and quality can be manipulated.

Table 3.3.11 - Gross margin scenarios growing oilseed flax

Assume:
- an oilseed variety is grown
- seed is sold for $7.00/bushel and straw for $10/tonne

		Seed Yield							
		5	10	15	20	25	30	35	40
Straw Yield	0.25	- 63	- 28	8	43	78	113	148	183
	0.50	- 60	- 25	10	45	80	115	150	185
	0.75	- 58	- 23	13	48	83	118	153	188
	1.00	- 55	- 20	15	50	85	120	155	190
	1.25	- 53	- 18	18	53	88	123	158	193
	1.50	- 50	- 15	20	55	90	125	160	195
	1.75	- 48	- 13	23	58	93	128	163	198
	2.00	- 45	- 10	25	60	95	130	165	200
	2.25	- 43	- 8	28	63	98	133	168	203
	2.50	- 40	- 5	30	65	100	135	170	205
	2.75	- 38	- 3	33	68	103	138	173	208
	3.00	- 35	-	35	70	105	140	175	210
	3.25	- 33	3	38	73	108	143	178	213
	3.50	- 30	5	40	75	110	145	180	215

▨ = most likely range of gross margins

extra field operations ($10-20) and possibly some lost net income from a non-flax crop the following year if the flax is left to ret in the spring of the following year ($30-60). After adding these extra $100/acre of costs to our oilseed production cost estimate of $100/acre we get an approximate variable cost of $200/acre for fiber flax. We then calculated gross margins for growing fiber flax and highlighted the most likely range of gross margins (Table 3.3.12). We can see that, in general, the gross margins from growing fiber flax are somewhat higher than growing oilseed flax but there are certainly some combinations where an oilseed crop could generate a higher gross margin. Critics will say that oilseed flax seed yields and prices could be higher than those shown but based on limited agronomic and processing trials with fiber flax in Saskatchewan, higher straw yields and prices could also be the case. Thus we should continue to look at both oilseed and fiber flax varieties as potential sources of fiber. However, many agronomic, harvesting and processing trials are needed over a multi-year period to better understand and clarify under what fiber and seed demand conditions each should be grown and to what extent straw yields and quality can be manipulated.

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		Seed Yield							
		5	10	15	20	25	30	35	40
Straw Yield	0.25	- 63	- 28	8	43	78	113	148	183
	0.50	- 60	- 25	10	45	80	115	150	185
	0.75	- 58	- 23	13	48	83	118	153	188
	1.00	- 55	- 20	15	50	85	120	155	190
	1.25	- 53	- 18	18	53	88	123	158	193
	1.50	- 50	- 15	20	55	90	125	160	195
	1.75	- 48	- 13	23	58	93	128	163	198
	2.00	- 45	- 10	25	60	95	130	165	200
	2.25	- 43	- 8	28	63	98	133	168	203
	2.50	- 40	- 5	30	65	100	135	170	205
	2.75	- 38	- 3	33	68	103	138	173	208
	3.00	- 35	-	35	70	105	140	175	210
	3.25	- 33	3	38	73	108	143	178	213
	3.50	- 30	5	40	75	110	145	180	215

☐ = most likely range of gross margins

Table 3.3.12 - Gross margin scenarios growing fiber flax

Assume:

- a fiber variety is grown
- cost of a fiber crop is, at the most, $100/acre more for a fiber flax crop due to higher costs for seed, possible extra field operations and late seeding of crop the following year
- seed is sold for $7.00/bushel and straw for $80/tonne

		Seed Yield							
		5	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Straw Yield	**0.25**	-145	-110	-75	-40	-5	30	65	100
	0.50	-125	-90	-55	-20	15	50	85	120
	0.75	-105	-70	-35	-	35	70	105	140
	1.00	-85	-50	-15	20	55	90	125	160
	1.25	-65	-30	5	40	75	110	145	180
	1.50	-45	-10	25	60	95	130	165	200
	1.75	-25	10	45	80	115	150	185	220
	2.00	-5	30	65	100	135	170	205	240
	2.25	15	50	85	120	155	190	225	260
	2.50	35	70	105	140	175	210	245	280
	2.75	55	90	125	160	195	230	265	300
	3.00	75	110	145	180	215	250	285	320
	3.25	95	130	165	200	235	270	305	340
	3.50	115	150	185	220	255	290	325	360

☐ = most likely range of gross margins

Table 3.3.12 - Gross margin scenarios growing fiber flax

Assume:
- a fiber variety is grown
- cost of a fiber crop is, at the most, $100/acre more for a fiber flax crop due to higher costs for seed, possible extra field operations and late seeding of crop the following year
- seed is sold for $7.00/bushel and straw for $80/tonne

		Seed Yield							
		5	10	15	20	25	30	35	40
Straw Yield	0.25	- 145	- 110	- 75	- 40	- 5	30	65	100
	0.50	- 125	- 90	- 55	- 20	15	50	85	120
	0.75	- 105	- 70	- 35	-	35	70	105	140
	1.00	- 85	- 50	- 15	20	55	90	125	160
	1.25	- 65	- 30	5	40	75	110	145	180
	1.50	- 45	- 10	25	60	95	130	165	200
	1.75	- 25	10	45	80	115	150	185	220
	2.00	- 5	30	65	100	135	170	205	240
	2.25	15	50	85	120	155	190	225	260
	2.50	35	70	105	140	175	210	245	280
	2.75	55	90	125	160	195	230	265	300
	3.00	75	110	145	180	215	250	285	320
	3.25	95	130	165	200	235	270	305	340
	3.50	115	150	185	220	255	290	325	360

▨ = most likely range of gross margins

4 Complimentary &/or Substitute Fibers

It is likely that cottonized flax will be used in blends with other fibers for a long time to come. Such blends will make spinning and weaving of cottonized flax easier but still give the customers most of the comfort and ecological friendliness of cottonized flax. Thus any estimates about future demand for cottonized flax would not be complete without a brief look at the present production levels of other textile fibers and their likely production and consumption in the future.

4.1 General Overview

The world-wide market for textile fibers is now between 44 and 47 Mt[26] per year (see Table 4.1.1). Of this total, about 24 Mt are man-made fibers and about 22 Mt are natural fibers. By far the biggest percentage of natural fiber usage consists of cotton (i.e., about 18 to 20 Mt) with only about 2.0 to 2.2 Mt consisting of other natural fibers (including 1.4 to 1.5 Mt of wool, 0.6 to 0.7 Mt of flax fibers, about 0.1 Mt of hemp and about 0.09 Mt of silk).

About 22 Mt of the man-made fibers are made from synthetic materials (e.g., polyester from petroleum derivatives) and the remaining 2 Mt are made from cellulosic material (e.g., rayon from wood pulp). Over time the percentage of man-made fibers produced from synthetic materials has risen relative to that produced from cellulosic materials and natural fibers (see Table 4.1.2). Part of the reason that synthetic fibers like polyester have become increasingly popular, relative to cellulose-based fibers like rayon is that the price of polyester has remained relatively constant while the price of rayon has continued to increase to the point where it is 50 to 70% higher than the price of polyester and cotton. Polyester has generally, but not always been slightly cheaper than cotton (see Table 4.1.3) and all synthetic fibers are easier to spin than cotton because the properties of synthetic fibers are very consistent and can be tailor made for the application.

Different regions of the world show differing patterns of fiber and fabric consumption. In general, developing countries use a high percentage of cotton based products while developed countries tend to have a much higher percentage of wool, silk, flax and man-made fiber products. The actual type and volume of textile fibers and fabrics that are used in a given country can be largely explained by population size, per capita income and type of climate.

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[26] In this report Mt refers to millions of metric tonnes

Table 4.1.1 - World textile fiber production, 1980-98

Year	Rayon And acetate	Non-Cellulosic fibers	Cotton	Wool (clean)	Silk	Flax	Hemp (soft) 1/	Total fibers
	--------------------------,000 tonnes--------------------------------							
1980	3,241	10,474	14,253	1,667	56	630	258	30,578
1981	3,204	10,825	13,820	1,687	57	611	223	30,371
1982	2,945	10,144	14,509	1,658	55	652	208	30,205
1983	2,928	11,074	14,313	1,705	55	786	184	31,646
1984	2,995	11,802	19,298	1,737	56	686	201	32,503
1985	2,931	12,487	17,479	1,731	68	745	218	34,926
1986	2,859	12,925	15,365	1,780	63	728	220	36,593
1987	2,825	13,738	17,638	1,850	63	956	215	37,285
1988	2,896	14,415	18,374	1,906	64	925	211	38,789
1989	2,942	14,745	17,361	2,010	66	816	180	38,119
1990	2,757	14,893	18,961	1,977	66	712	165	39,530
1991	2,433	15,273	20,697	1,782	67	699	199	41,150
1992	2,327	16,158	17,982	1,721	67	673	196	39,123
1993	2,345	16,583	16,886	1,676	68	621	118	38,297
1994	2,307	17,936	18,698	1,559	69	572	95	41,235
1995	2,423	18,374	20,348	1,489	92	697	101	43,524
1996	2,269	19,903	19,600	1,492	88	657	63	44,073
1997	2,314	22,148	20,015	1,443	87	635	67	46,708
1998	2,185	22,737	18,426	1,415	87	646	69	45,564

1/ Hemp starts a new series in 1996.

Source: International Wool Textile Organization.

Table 4.1.2 - World textile fiber production market share, 1980-98

Year	Rayon and acetate	Non-Cellulosic fibers	Cotton	Wool (clean)	Silk	Flax	Hemp (soft) 1/
			%				
1980	10.60	34.25	46.61	5.45	0.18	2.06	0.84
1981	10.55	35.64	45.50	5.55	0.19	2.01	0.73
1982	9.75	33.58	48.04	5.49	0.18	2.16	0.69
1983	9.25	34.99	45.23	5.39	0.17	2.48	0.58
1984	9.22	36.51	59.37	5.35	0.17	2.11	0.62
1985	8.39	35.75	50.05	4.96	0.19	2.13	0.62
1986	7.81	35.32	41.99	4.86	0.17	1.99	0.60
1987	7.58	36.85	47.31	4.96	0.17	2.56	0.58
1988	7.47	37.16	47.37	4.91	0.16	2.38	0.54
1989	7.72	38.68	45.54	5.27	0.17	2.14	0.47
1990	6.97	37.67	47.96	5.00	0.17	1.80	0.42
1991	5.91	37.12	50.30	4.33	0.16	1.70	0.48
1992	5.95	41.30	45.96	4.40	0.17	1.72	0.50
1993	6.12	43.30	44.09	4.38	0.18	1.62	0.31
1994	5.59	43.50	45.34	3.78	0.17	1.39	0.23
1995	5.57	42.22	46.75	3.42	0.21	1.60	0.23
1996	5.15	45.16	44.47	3.38	0.20	1.49	0.14
1997	4.95	47.42	42.85	3.09	0.19	1.36	0.14
1998	4.79	49.90	40.44	3.11	0.19	1.42	0.15

1/ Hemp starts a new series in 1996.

Source: International Wool Textile Organization.

Of all fibers used in textiles, cotton still has the biggest share, largely because it is the cheapest natural fiber,[27] it can be easily produced in very large volumes, it has wide appeal among consumers and about 90% of the world's textile spinning and weaving equipment are able to use cotton. In general, man-made fibers are as cheap as cotton but are much more resistant to wear and do not crease as easily. However, man-made fibers do not, in general, feel as comfortable as natural fibers. This has encouraged textile processors to use blends of cotton and man-made fibers to produce fabrics with the comfort of natural fabrics but with the easy care and durability of man-made fabrics. Apart from silk, all natural fibers have relatively short fibers and can only be formed into long lengths by twisting the fibers together to form "spun" yarn. Over the centuries, yarn and fabric construction have evolved to allow the production of yarns and fabrics with a very wide variety of properties to suit particular uses.

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[27] From lowest to highest per kilo values, natural fibers can be ranked as follows: cotton, ramie, flax fiber, wool and silk.

Table 4.1.3 - Fiber prices and ratios

	Cotton /a		Rayon /b		Polyester /c		Price ratios /d	
Calendar Year	Actual	Raw-fiber-equivalent /e	Actual	Raw-fiber-equivalent /e	Actual	Raw-fiber-equivalent /e	Cotton/ rayon	Cotton/ Polyester
Cents/lb								
1980	87.98	97.76	74.5	77.6	74.33	77.43	1.26	1.26
1981	80.41	89.35	86.5	90.1	84.75	88.28	1.00	1.01
1982	68.00	75.55	84.50	88.02	76.75	79.95	0.86	0.95
1983	77.72	86.36	80.25	83.59	73.00	76.04	1.03	1.14
1984	76.06	84.51	84.00	87.5	78.83	82.12	0.97	1.03
1985	65.83	73.15	78.83	82.12	66.33	69.10	0.89	1.06
1986	60.99	67.77	75.75	78.91	62.33	64.93	0.86	1.04
1987	72.71	80.79	81.00	84.38	65.75	68.49	0.96	1.18
1988	64.89	72.10	90.67	94.44	73.83	76.91	0.77	0.94
1989	71.99	79.99	109.75	114.32	85.67	89.24	0.70	0.90
1990	79.29	88.10	119.92	124.91	82.58	86.02	0.71	1.03
1991	79.05	87.83	122.00	127.08	73.50	76.56	0.69	1.15
1992	61.92	68.80	114.08	118.84	73.50	76.56	0.58	0.90
1993	62.43	69.37	111.42	116.06	72.50	75.52	0.60	0.92
1994	78.69	87.43	103.00	107.29	74.92	78.04	0.82	1.12
1995 /f	102.88	114.31	117.40	122.29	88.60	92.29	0.94	1.24

Source: USDA-ERS

NOTE: Landed Group B mill points, cotton prices, and manmade staple fiber prices at f.o.b. producing plants, actual and estimated raw-fiber-equivalent, 1960-95

a/ 1960-69, middling 15/16" at Group B mill points, net weight; 1970 to date, SLM 1-1/16".

b/ 1.5 and 3.0 denier, regular rayon staple.

c/ Reported average market price for 1.5 denier polyester staple for cotton blending.

d/ Raw-fiber-equivalent.

e/ Actual prices converted to estimated raw-fiber-equivalent as follows; cotton, divided by 0.90; rayon and polyester, divided by 0.96.

f/ Average for January - October

In the 1920s, factories started producing large quantities of man-made fibers that were initially meant to imitate silk. They were made into continuous filament yarns and many had the properties of silk (i.e., they had a luster or sheen and could be made into sheer fabrics which had good draping properties with a cool touch). However, since that time, over half of all man-made fibers are now made in the form of staple fiber (i.e., short, crimped fibers) so that they are similar to cotton fibers in length and diameter and can be spun on the "cotton system" to produce pure or blended yarns.

There are several reasons why a large percentage of man-made fibers are cut and processed into short cotton-like fibers. In an industry geared to processing mainly cotton, newly introduced man-made fibers would have met with considerable market penetration problems if they had not been in the form of short fibers that could be used with the textile machinery that was being widely used at that time. In addition, most clothes worn outside the tropics need to provide warmth, "opacity" (i.e., the opposite of transparent), and fullness. These properties can be easily provided by fabrics made with cotton and wool but would be difficult to obtain with long silk-like fibers.

Crimped staple fibers, when twisted together, form a relatively bulky "bundle" with many free ends on the surface. When made into fabric, the combination of surface hairs and bulky yarn construction (compared with that of a continuous filament yarn) entraps appreciable amounts of air which provides good heat insulation. The relatively random array of fibers also produces opacity and provides an attractive matt appearance. Because a typical fabric made with staple fiber yarns contains less than 10% of fiber by volume and more than 90% of still air, it has good thermal resistance, depending only on fabric thickness and not on fiber type.

While much man-made staple fiber is used in 100% constructions, there are considerable advantages in using it in blends with natural fibers or other man-made fibers. A most successful combination is that of polyester and cotton for shirts, blouses, sheets and rainwear. The comfort of cotton is largely retained while the polyester gives much increased durability, easy washing and drying with good retention of intentional creases and shedding of unintentional ones. This is in keeping with a general trend in textiles toward blended fabrics with a natural look and feel but with the easy care and convenience of man-made fibers.

There are many reasons why a particular yarn is used in fabric. The most general reason is fitness for purpose, technically and aesthetically but another important factor is its price. In general, man-made staple fibers are cheaper than natural fibers, however, many consumers will not buy textiles made from 100% man-made fibers even if they are cheaper. Thus the apparel fabric manufacturer must make compromises between appearance, performance, and cost. There is, of course, no simple answer. The choice depends very much on the end-use and the section of the textile market that is being targeted.

4.2 Cotton

Cotton fiber has been used in apparel for very long periods, though not in large quantities before the nineteenth century. It is estimated that at the end of the eighteenth century, cotton filled only 4% of demand for textile fibers, compared to 78% for wool and 18% for flax (linen), but a century later, market segments were quickly reversed and cotton filled 78% of the market, with wool and flax taking up about 21% of market and silk, about 1%. This dramatic switch was caused by:

i) the development of new low cost methods to spin and weave cotton and wool during the initial part of the Industrial Revolution;

ii) the invention of the cotton gin which enabled one person to clean the seeds out of about 40 kilos of raw cotton per day when formerly only about one kilo a day was possible (this obviously had a great effect on lowering the cost of processing cotton);

iii) plantation owners in the New World who found it extremely profitable to expand cotton production because of their very low costs of production; and

iv) rapidly rising incomes of many Europeans during the Industrial Revolution (this provided the means for people to buy cotton fabric and garments which had historically been high priced luxury items for the rich).

Market Shares and Trends

China, the US, India, and Pakistan are the largest producers of cotton, however, the US is, by far, the largest exporter of cotton. Between them China and India produce and consume about 40% of the world's cotton (see and Table 4.1.1 and Table 4.1.2). Over the last 20 years world cotton prices have varied from about US$0.50 to 0.90 per pound (i.e., US$1.10 to 2.00 per kilo) with a long term of about US$0.70/lb (i.e., $1.54/kilo).

New technology in spinning and weaving processes, combined with low wages and production costs, have enhanced Asian countries' competitiveness in producing cotton yarn and fabric and the Asian share of the world textile market has grown substantially to the point of dominating global production. Most of this gain came at the expense of Europe, and other high labor cost countries. Within Asia, production has steadily shifted from East to Southeast Asia.

Table 4.2.1 - World cotton production

(millions of tonnes)	95/96	96/97	97/98	98/99	99/00
					May
United States	3.90	4.11	4.09	3.03	3.70
China	4.77	4.20	4.59	4.51	3.83
India	2.90	3.03	2.68	2.76	2.79
Pakistan	1.79	1.59	1.57	1.37	1.79
Uzbekistan	1.24	1.04	1.13	1.00	1.15
African Franc Zone	0.67	0.81	0.94	0.89	0.89
Turkey	0.85	0.78	0.81	0.85	0.87
Australia	0.44	0.61	0.67	0.72	0.70
Argentina	0.41	0.33	0.30	0.20	0.13
Brazil	0.39	0.28	0.39	0.46	0.57
Greece	0.46	0.30	0.35	0.39	0.41
Egypt	0.24	0.35	0.35	0.24	0.24
Turkmenistan	0.26	0.13	0.20	0.22	0.24
Mexico	0.22	0.24	0.22	0.22	0.13
Paraguay	0.11	0.04	0.09	0.07	0.09
Tajikistan	0.13	0.09	0.11	0.11	0.09
Other	1.48	1.57	1.48	1.37	1.39
World Total(Mt)	20.2	19.5	20.0	18.4	19.0
World Total (millions of 480lb bales)	93.0	89.6	91.7	84.5	87.3

Source: USDA

Relevance to the Projected Market for Cottonized Fiber Flax

The heat and humidity in most highly populated parts of Asia will encourage people to continue to wear clothes made of pure natural fibers or blends containing natural fibers. Cottonized flax blended with cotton offers a fabric that is even cooler than cotton and offers garment makers and retailers a way to charge more for a garment than if the garment in question were made from pure cotton. Such cotton/flax blended garments might cost US$1.00 more per garment for the raw material but retail prices could be US$2.00 to 20.00 higher because such garments could promoted be as being better and more exclusive than pure cotton garments.

Table 4.2.2 - World cotton consumption

(millions of tonnes)	95/96	96/97	97/98	98/99	99/00 May
China	4.29	4.42	4.27	4.18	4.72
India	2.61	2.85	2.76	2.72	2.87
United States	2.33	2.42	2.48	2.26	2.20
Pakistan	1.57	1.52	1.57	1.52	1.61
European Union	1.13	1.15	1.18	1.09	1.09
Turkey	0.96	1.02	1.09	1.00	1.18
Brazil	0.85	0.85	0.74	0.76	0.85
Indonesia	0.46	0.46	0.41	0.50	0.52
Mexico	0.24	0.35	0.44	0.48	0.52
South Korea	0.37	0.33	0.30	0.33	0.35
Japan	0.33	0.30	0.30	0.26	0.26
Taiwan	0.30	0.28	0.28	0.30	0.30
Thailand	0.30	0.30	0.28	0.28	0.30
Russia	0.26	0.24	0.26	0.20	0.33
Other	2.76	2.66	2.66	2.61	2.59
World Total(Mt)	18.8	19.2	19.0	18.5	19.7
World Total (millions of 480lb bales)	86.9	89.1	88.5	85.0	90.5

Source: USDA

The fact that more and more cotton processing has shifted to Asia means that the biggest volume markets for cottonized flax fiber will almost certainly be in Asia, both for garments for export and for garments for internal use. Unlike Europe and North America, the textile processors in East and South Asia must, in the long run, continue to import their cottonized flax requirements because they do not have a climate suitable to grow flax[28]. Thus if Canadian producers of cottonized flax can establish a market for cottonized flax in Asia, that market is likely to stay for a long time. However, since more and more textiles are being spun on open end systems, there will be an increasing need to have cottonized flax which has a finer and more regular staple.

4.3 Ramie

Ramie *(Boehmeria nivea)* is a natural woody bast fiber that has often been sold as a substitute for flax. Also known as *ramee*, *rhea* and *China grass*, it is a tall, herbaceous nettle-like plant that grows best in semi-tropical regions of the world that have abundant rainfall (e.g., southeastern Asia, China, Brazil). It is often grown on hillsides, especially in China. It has tall upright stems that grow from one to two meters in height. These stems are cut at maturity because immature stems yield coarse, brittle fibers. However, once the stems are cut they send up a new set of stems. Hence ramie can be cut from three to five times in one growing season. Ramie plants can last for many years, if they are not attracted by disease and/or if soil fertility is maintained.

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[28] Most East and South Asian countries must also import cotton because the long rainy season and/or high humidity cause so many harvesting and disease problems that production of cotton is severely constrained.

Ramie stems contain long fibers that are closely bound by pectins to the cellulose of the stems. These fibers are held more tightly than in plants like flax, hemp and jute and, as a consequence, ramie fibers are always bleached during the preparation of the fiber because such bleaching dissolves pectins and hence releases the finer fibers that make up the coarser fiber bundles. In general, the release of these fine fibers is not possible with standard retting techniques that are used in jute, hemp and flax. Ramie fibers are stiff, more brittle than linen, and highly lustrous. It can be bleached to extreme whiteness. Ramie lends itself to general processing for textile yarns, but its retting operation is difficult and costly, making the fiber unprofitable for general use. When combed, ramie is half the weight of linen, but much stronger, coarser, and more absorbent. It has permanent luster and good affinity for dyes and it is little affected by moisture. Ramie is used as a filling yarn in mixed woolen fabrics, as adulteration with silk fibers, and as a substitute for flax fibers. Ramie fibers are long but they can be cottonized for use in blends.

Ramie fibers range from 6 to 45 cm in length (i.e., 2.5 to 18.0 inches) and from .002 to .003 inches in diameter (i.e., finer than flax fibers but not as fine as silk)[29] and are very strong. One authority states that ramie is seven time stronger than wool and twice as strong as flax, especially when it is wet. Its smooth, lustrous appearance seems to improve with washing. Ramie fabrics keep their shape and do not shrink. They resist mildew, absorb more moisture than linen and dry quickly. They dye easily, but the fibers are brittle and have low twisting and bending strength; hence processors have difficulty spinning it pure. If it is spun pure on the worsted system, the fibers must be cut into staple lengths but the resultant fabrics are quite coarse. Finer pure ramie fabrics can be produced if the whole length of the fiber is used (i.e., if it is not cut into staple lengths) but then it must be spun on the more expensive silk system. Cutting and mixing ramie with other fibers and then spinning solves many of these problems.

Traditionally ramie had been a very labor intensive crop and its use was restricted to very small volumes of production in very localized areas of the tropics. During the Second World War, research work by the United States Department of Agriculture led to the growing of ramie in Florida. This research was aimed at finding a method of recovering and refining ramie fibers on a large commercial scale. However, by the time several new techniques had been developed, the war was over and commercial interest in a US ramie industry declined. In the 1970s, some of the methods developed in the US (e.g., commercial scale chemical bleaching of fibers) were tried in several developing countries. These techniques made the production of ramie commercially attractive in parts of Central and South America and in parts of China and Southeast Asia.

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[29] In contrast, the diameter of silk fibers ranges from .00059 to .00118 inch.

China produces the majority of the world's supply of ramie; the Philippines and Brazil are also producers, however, production in Brazil is dropping very quickly. The quality of ramie from the Philippines is considered the best in the world and hence has the highest price, but even in the Philippines production has dropped dramatically since the mid-1980s. Ramie production is still quite labor intensive and at present prices many farmers find the return to a day's labor is often much higher growing a crop other than ramie. However, every four or five years, ramie becomes a popular novelty fiber and at such times ramie prices soar, only to be followed by a price crash a year or two later. Ramie production could expand if changing fashion tastes increased the demand for ramie and/or if a new technology were developed to mechanize production.

Relevance to the Projected Market for Cottonized Fiber Flax

The price of ramie has generally been higher than cotton but lower than long line flax fiber. If it stays in this price range it is likely that ramie production will continue to decline unless a lower cost technology is developed to grow and process ramie (i.e., the big jumps in ramie production occur when ramie prices rise to prices similar or even higher than long line flax fiber prices). Industry sources suggest that China may now be responsible for about 90% of the world's ramie production, but even in China ramie production has dropped significantly in the last few years. If cottonized flax fiber prices were to drop to the level of ramie prices, and if buyers were happy with the volumes of cottonized flax being offered, then it is very likely that 50 to 60% of the ramie market could be taken over by cottonized flax (i.e., some demand would still remain for ramie because of its greater luster and softness).

4.4 Hemp

Hemp (*Cannabis sativa*) is one of the oldest crops known to man and has been cultivated since ancient times for the provision of fiber for many purposes. It is a fast growing annual and has been grown in most temperate and tropical countries of the world. There are more than thirty varieties of hemp but all resemble one another in general appearance and properties, but only some contain fibers that have high tensile strength, fineness and high luster. Hemp must pass through a retting process and subsequent manufacturing operations that are similar to those used for flax. At first glance, the fiber resembles flax fiber, however, hemp is harsh and stiff and cannot be bleached without harm to the fiber. As hemp is not pliable and elastic, it cannot be woven into fine fabrics. Hemp is durable and is often used in carpet and rug making. It is also very suitable for use in making ropes and sailcloth because it is not weakened or rotted by water.

There has, however, been a worldwide decrease in the amount grown over the last 20 years though it is possible that this trend is about to be reversed due to changes in government policy in some developed countries. Relative to most other natural fibers, the cost per hectare to produce hemp are quite low and the yield of fiber is quite high. Yields of plant material range from seven to fifteen tonnes/ha and the fiber content can range from 20 to 30% to give a fiber yield per hectare ranging from 1.4 to 5.0 tonnes/ha. If yields and fiber content are high, hemp is price competitive with wood pulp for certain types of paper and could even be price competitive with some synthetic fibers for certain textile and industrial products (e.g., in carpets, fire hoses, etc.).

Production of hemp is still large in countries that have a long history of growing it and include China, India, the Former Soviet Union and many Eastern European countries. Hemp in these countries is largely used to make rope, bindings, backing for items like carpets and for specialized papers (i.e., very little or none is presently cottonized). However, even in these countries, hemp production has been declining. This drop in production, has been however, countered somewhat the growing of industrial hemp in countries that had formerly banned it because of its close association with the growing of marijuana.

History of Hemp

Production of hemp originated in Central Asia over 8,500 years ago. From the 16th to the 18th century, hemp and flax were the major fiber crops in Russia, Europe and North America. During the late 19th and early 20th centuries, increasing labor costs encouraged a shift away from hemp to cotton, jute and tropical fibers which were less labor intensive. Technological advances, such as the cotton gin, encouraged production of competitive crops. This decline has continued, due to the advent of synthetic fibers and because the cultivation of hemp has been made illegal in many countries. In 1937, the United States government imposed a heavy tax on producers under the Marijuana Tax Act. Canada prohibited production in 1938 under the Opium and Narcotics Control Act. During World War II, the Canadian and US governments lifted the restrictions on hemp production to provide materials for the war effort.

World production peaked in 1940 at about 832,000 tonnes of fiber. After the war, the restrictions were reapplied in many countries. In the 1990s, world production of hemp fibers has varied between 100,000 to 200,000 tonnes annually with India, China, Russia, Korea and Romania as the leading producers.

Agronomic Characteristics

Agronomic Characteristics

Hemp is a herbaceous annual that can reach up to nine meters in height, but under cultivation it averages between two to four meters. In four months it can produce seven to 15 tonnes per hectare (t/ha) of dry stalk. It is dioecious (having male and female flowers borne on separate plants), but monoecious cultivars have been bred. Modern plant breeding in Europe has produced several dozen hemp strains with the emphasis on the creation and perfection of monoecious varieties. Selecting monoecious strains overcomes the problem of different maturation times between male and female plants, and results in consistent height and weight of the stalk for more uniform quality and higher productivity. Hemp is a short-day plant, and since production has historically been concentrated in north-temperate areas, fiber selections are generally photoperiodically adapted to mature in early fall.

The plant can be harvested for seed but historically the stalks have been considered to be more valuable than the seed. The stalk is harvested for the fiber and **hurds**. The center of the stalk is hollow except at the nodes (where the leaves are attached) and in the best fiber producing types the hollow space occupies at least one-half the diameter. Next is the inner-most layer or pith surrounded by thick, short woody cells which support the plant during its growth. The adherent woody core, after it is freed by retting, is referred to as hurds. Outside of the hard woody portion is the soft cambium, or growing tissue which develops into the hurds on the inside, or into the bast and bark on the outsides. It is in this layer that the fiber bearing bast splits away from the hurds during retting and breaking. Outside of the cambium is the phloem parenchyma, comprised of short, thin-walled cells, filled with chlorophyll, giving it a green color, and long thick walled cells, making the bast fibers. Between 15 to 35 fiber bundles are found in this layer. Outside of the primary bast fiber is the cortex, which is a continuation of the thin-walled chlorophyll-bearing cells free from fiber. The outside of the stalk is covered by a thin epidermis.

There are three types of fiber: primary bast fibers which are long and low in lignin, secondary bast fibers which are of intermediate length and high in lignin content and libriform fibers which are short and high in lignin. Fiber length and the contents of cellulose and lignin are important quality parameters for raw materials used in the cordage, textile, paper and fiberboard industries.

Hemp seed can be eaten as is, roasted and ground, de-hulled or crushed into oil. The oil can be used for both food and non-food uses. In the last decade hemp seed and hemp oil have become very popular among certain segments of the population in developed countries, both for its health giving and taste properties but also for its novelty and trendiness.

Hemp hurds refer to the portion of the stem after the seeds and fibers have been removed. Hemp hurds look somewhat like small pieces of very dirty Styrofoam. They are highly absorbent and have become very popular as horse bedding. In fact in England and Germany it is said that hemp-processing plants get more net revenue from hemp hurds than from hemp fiber.

Hemp grows best in a humid environment when the ambient temperature ranges between 14^{0}C and 27^{0}C, although it can endure greater temperature variations. Hemp grows best with plenty of rainfall during the growing season, especially during the first six weeks. Once well rooted, hemp can endure dry conditions although it hastens maturity, dwarfs growth and reduces yields. Depending upon the area and rainfall conditions, hemp is usually planted between early March and late May in the northern latitudes when the ambient temperature is around 10^{0}C. Seedlings can survive a short frost of -8 to -10^{0}C while older plants tolerate frosts of -5 to -6^{0}C. Since hemp is sensitive to photoperiod, the earlier plantings produce bigger fiber yields.

Harvesting of hemp for high quality fiber occurs as soon as the crop is in flower. Harvesting for seed production and fiber occurs four to six weeks after flowering, however, at this stage, the fiber will be of poorer quality because lignification of the bast fiber will make it stiff and coarse. If the goal is maximum stem yield, the implication for fiber hemp breeders is clearly to breed late- or non-flowering cultivars.

Equipment developed for other fiber crops, such as kenaf, may be used for hemp with minor modifications. Attempts at using sickle mowers, haybines and round balers have been used with some success depending on the end use of the hemp stalk. Requirements for chopped stalk by the pulp and paper and fiberboard industry would allow the use of these types of equipment.

Harvesting hemp for the long bast fiber for the cordage and textile industries requires the fiber to be undamaged. To date, this has largely constrained the use of haybines and balers. To ensure the long bast fibers are undamaged and can be easily cleaned, a retting process is required.

Retting

This is the process of decomposition by bacteria and molds by which the pectin that binds the fiber and the non-fibrous portion of the stalk is broken down. Once the binding agent is broken down, the fiber and the stalk are easily separated. There are several different retting procedures that can be used.

Dew retting is the traditional method induced by frequent rains and dews. After the hemp stalk is cut, it is spread evenly on the ground to allow decomposition of the pectin. There is a fine line between retting and rotting. If continued wet weather prevents the straw in the field from being lifted at the proper time, it becomes over-retted and is of little value. Without the proper equipment dew retting is labor intensive. It may take one to two weeks if the weather is warm and humid, but usually four to five weeks are required. The retting process is followed by a period of drying and the bunches are then stored for further processing. The fiber from dew retted hemp is light brown in color and rather coarse. It is used primarily for twine, cordage and fine paper.

In **water retting** bundles of hemp are submerged in clear water to allow bacterial activity to break down the pectin. The average retting period is seven to ten days after which the retted bundles are then rinsed, washed, sun-dried and stored for fiber extraction. Although water retting is more costly than dew retting, the fiber is of a higher quality. It can be combed one or more times, refined, dyed, spun and woven to whatever extent is required for cable, rope, string, thread, cloth, clothing, etc.

Warm water retting is similar to water retting but the hemp is soaked for 24 hours before new water is added and brought to an elevated temperature for about two to three days. A very uniform, clean fiber is produced.

In **green retting** green stalks are mechanically processed to separate the fiber from the stalk. The high quality fiber can be refined for the textile industry while the remaining stalk can be used in the paper and fiberboard industries.

In **chemical retting** hemp stalks are placed in a processing tank where chemical agents are used to dissolve the pectin. By maintaining a constant processing temperature the retting time can be reduced to 48 hours while producing a very high quality fiber.

After the retting process the hemp fiber and the stalk are loosely held together and must be decorticated, scutched, hackled and combed to remove the remaining pieces of stalk, broken fibers and extraneous material. Mechanical decortication equipment can be used in conjunction with turbine scutchers to separate the fiber and the nonfibrous portion of the stalk. Inventors and implement companies are working together developing machinery to more efficiently and cheaply harvest and process hemp for the textile, paper, fiberboard and seed industries.

Relevance to the Projected Market for Cottonized Fiber Flax

In Europe, before the 1800s, hemp, along with wool and flax, were the main sources of fiber used to produce clothing in Europe. Hemp fibers are relatively coarse and in traditional fiber preparation systems, hemp clothing was very strong but had a coarse texture and feel. The technology now exists to cottonize hemp and blend it with other fibers to create yarns and fabrics with improved properties or lower cost than other cottonized fibers. This allows the production of much finer yarns and fabrics than have traditionally been possible but spinners and weavers claim that hemp suffers from an "image problem" and that it cannot be introduced into large volume textile goods until its name is changed to something other than hemp. They claim that fashion designers and even many consumers immediately think of a coarse, rough yarn and fabric when they hear that it is made from hemp. The potentially lower cost of cottonized hemp, compared to cottonized flax or ramie, would make cottonized hemp attractive for some uses but its lower moisture holding ability compared to cottonized flax fiber would make it less attractive in the fine garment market (i.e., shirts, blouses, skirts, dresses). Its lack of softness would make it less attractive than ramie in such things as women and children's clothing.

4.5 Polyester

In the last decade, polyester has become the world's most important synthetic fiber and its name has become familiar to most shoppers. There are a number of reasons for this wide use of polyester. Most important are its properties of easy care and toughness while its relatively low price obviously has a marked influence on its universal acceptance. Polyester has come to dominate world production of synthetic fibers.

Properties

Polyester is similar to nylon in many respects in that fibers formed from both of them are strong with high abrasion resistance and low moisture absorption. Both are resistant to rot and chemicals and can be set into shapes by the application of heat. Polyester, however, has become far more important than nylon. This has happened because of relatively slight but important differences in its properties compared with those of other synthetics and production costs lower than those of nylon.

One of the most important properties of a fiber is its resistance to stretching. While tenacity (breaking load divided by fiber weight per unit length, expressed in textile units) is an important measure, the fibers or yarns in apparel are seldom stretched to their breaking point. The handle or feel of the fabric is more influenced by the modulus of the fibers (i.e., their resistance to small extensions and bending). The modulus of polyester is about double that of nylon which tends to give fabrics containing polyester a crisper handle and good dimensional stability. Loads that would break viscose and acetate fibers will only produce a stretch of 2% or so in polyester.

The recovery of polyester fibers from stretching and bending, as occurs in creasing, is good, surpassed only by nylon. This ability of polyester fabrics, after heat setting, to retain a flat shape by shedding accidental creases but also to retain pleats and fashion creases set into the fabric, is a major advantage.

All textile fibers creep (i.e., slowly stretch when under an applied load for long periods). In many cases this creep is large and irreversible. Polyester, however, exhibits quite low values. For example, at a load equal to one-fifth of the breaking load applied continuously for ten years, polyester would be expected to creep by only 1%, which makes it suitable for many industrial applications like ropes, conveyor belts, sails, and tarpaulins. Good abrasion resistance is also important in industrial applications, and of value in apparel, where polyester outperforms all natural fibers and is second only to nylon.

Polyester's easy-care properties are helped by a very low value of moisture absorption. Under normal atmospheric conditions it absorbs only about 0.4% water compared with 4% for nylon, 8% for cotton and 12% for linen. After spin drying, polyester fibers hold only 4% water compared with 15% for nylon and 50% for cotton. The structure of polyester is hardly changed by this low water absorption and the result is that its strength is little affected when wet. It also dries very quickly.

However, low water absorption has its disadvantages. In certain fabric constructions, garments next to the skin are clammy and uncomfortable in warm weather. Low moisture content can also increase the tendency for garments to build up charges of static electricity that will cause clinging and will attract dirt. Resistance to moisture absorption also causes difficulties in dyeing. All of these potential drawbacks can be and are overcome by correct yarn and fabric construction, often including water-absorbent fibers such as cotton or wool, by the use of suitable antistatic treatments, and by methods that swell the polyester fiber to allow the entry of dyestuffs into the molecular structure.

When polyester is heated it does not remain hard until it reaches its melting point. Because of its complex structure the molecular bonds holding it together start to rupture above the so-called glass transition temperature of about 90^0 C. More and more bonds break as the temperature continues to rise so that the polymer becomes increasingly softer until it melts at about 250^0 C. Over a range of temperatures below the melting point polyester is plastic (i.e., it deforms easily and does not recover from the deformation). Because of this thermoplastic property, yarns and fabrics heated to temperatures between about 150^0 C and 200^0 C can be permanently modified in shape (i.e., they can be "heatset"). This set will be relatively unaffected by other treatments at temperatures substantially lower than the heat-setting temperature, so that a fashion pleat, for example, set at 180^0 C would be relatively unaffected by hot washes. This property is widely used to set fabric flat so that it does not hold accidental creases and to impart crimp and texture into yarns to give them added bulk and stretch properties.

Uses of Polyester

Polyester fiber and yarns are very widely used in apparel and in fabrics for domestic and industrial applications. In apparel, apart from the needs of fashion and style, the main requirement is for comfort, including warmth and opacity, at reasonable cost. These, in the past, were well provided by natural fibers such as cotton and wool and it is not surprising that a large proportion of all manmade fibers have been modified to change their appearance from the 'artificial silk" look of continuous filament yarn to that of staple (i.e., short fiber) cotton and wool. This is achieved by crimping and cutting them into staple fibers. In the last ten years over 70% of cellulosic manmade fiber and over 50% of synthetic fiber have been made into staple fiber, much of it to be processed on cotton or wool processing machinery. Polyester is part of that pattern.

With suitable constructions, 100% staple fiber polyester yarns can be made into fabrics resembling woolen or worsted fabrics, usually for outerwear dresses or suits. These can be very attractive and hardwearing with the further advantage of easy washing and drying (e.g., even men's suits can be machine-washed and dried with no shrinkage or loss of appearance). These advantages have to be balanced against a slightly harsh handle, low moisture absorption, and a tendency to show snags and pilling. These last disadvantages occur because the tough polyester fibers do not easily break. The little balls of surface fiber that are formed when fabric rubs against itself do not rub off as do those formed of weaker fibers, and any snags do not break the yarn but pull and distort the garment construction, causing an obvious fault.

Women's blouses in 100% polyester are also very common. Their silk-like appearance, low cost and easy-care properties make them very popular. Good crease recovery, easy cleaning and a silky appearance also explain the popularity of 100% polyester ties.

Not much unmodified continuous filament polyester yarn is used for apparel because it is too cool and translucent for most garments. However, it can be textured to give it improved aesthetic properties. In the 1960s and 1970s most textured polyester yarns went into weft knitted fabrics for women's dresses and trouser suits. Their then novel features of seemingly wool-like appearance with hard-wearing, easy-care properties at low cost made these garments extremely popular for a number of years, especially in developed countries. This created a very large market and about two-thirds of all continuous filament yarn used in apparel was textured and was responsible, first, for the explosive growth of polyester and, secondly, for the major problems of over capacity in the 1970s. Since then, there has been a shift towards the look and feel of natural fibers in apparel, and fabrics made of 100% textured polyester have greatly declined in popularity.

Polyester in Blends

One usually associates comfort with natural fibers while synthetic fibers are felt generally to have good wear resistance and easy-care properties. A good example of this is the easy-care and long life of the not-too-comfortable 100% nylon warp knitted shirts popular some years ago compared with the comfort but more difficult washing and ironing of the 100% cotton shirt. It is not surprising that efforts have been made to try to get the advantages of both types of fiber into one fabric. This has been done with outstanding success by blending polyester and cotton fibers. These two fibers blend together very well because the polyester has been developed to have physical characteristics similar to those of cotton. Cotton/polyester blend ratios vary from 50:50 to 80:20, but the most common is 67:33. At this level the polyester dominates the cotton as far as crease shedding, appearance retention, and easier washing and drying are concerned but the comfort and feel of the blended fabric is still quite close to that of a 100% cotton fabric. Polyester/cotton blends are widely used in shirts, blouses, bed sheets, trousers and rainwear. Hardwearing workwear is another important end-use.

The popularity of polyester/cotton blends is due, not only to the easy care that polyester brings to cotton, but to the much-improved abrasion resistance and tear strength resulting from the presence of the polyester. For example, a bed sheet containing 67% polyester has its life at least doubled compared to that of a 100% cotton sheet of similar construction. Quoted values (*Textiles* 1980, Vol. 9, No.2) are: 100 cycles of wear for a 100% cotton sheet before failure compared with 300 to 400 cycles for the blended sheet. Shirts, blouses, and dresses made from polyester/cotton experience similar benefits in extended life. Probably the biggest advantage, however, is the ability to take the shirt, sheet, or blouse from the tumble dryer and to fold it away virtually free of creases without the need to iron. This is due to the ability of the polyester component to retain the flat appearance that was heatset into it during the final stages of manufacture of the cotton/polyester fabric.

Another very good blend between a synthetic and a natural fiber consists of polyester and wool. As with cotton, the presence of the polyester adds abrasion resistance, increased wear life, appearance retention, and crease shedding to the wool. This blend is used very successfully in suiting fabrics and medium-weight dress fabrics. Its ability to hold fashion pleats in skirts and creases in trousers is a particular advantage. A popular polyester/wool blend is 55% polyester and 45% wool. The handle of such a fabric is similar to that of wool (perhaps a little crisper) and the warmth and moisture absorption are not noticeably different from those of a 100% wool fabric. The benefits given by the presence of the polyester, in addition to a price advantage, are evident in damp conditions when the intentional creases and pleats remain and unintentional creases do not form.

Market Shares and Trends

The last decade has seen rapid growth in the economies of most East and Southeast Asian economies and more especially in China, Korea, Taiwan, Malaysia, Singapore and Indonesia. These changes have provided increased opportunities in trade and commerce, including the textile industry and, in particular, polyester. The rapid growth of polyester production and the industries that convert polyester to intermediate and finished goods is also representative of a global business without traditional boundaries. In the past decade, polyester has continued to enter new markets and find use in new applications, growing by 8% annually. Much of this growth has taken place in the Asia-Pacific region and about 75% of all polyester is used in textile and industrial fiber production.

Since the 1960s polyester and cotton have combined to make up about two-thirds of the world textile fiber market. Polyester is both a substitute and a compliment for cotton. Based on performance and the limitations of cotton production, polyester has been continually taking market share from cotton. Currently polyester has 20-25% of the total world fiber market. Factors behind this trend could easily push polyester's worldwide market share to 30% within ten years. Over the last two decades polyester production and consumption has increasingly shifted from North America and Europe to Asia and the Pacific Rim. This shift in fiber production has followed the movement of textile operations to lower labor-cost regions. Once these labor intensive operations had relocated to Asia and the Pacific Rim, the distribution costs of raw materials created an incentive to put the entire production chain closer to the manufacture of the finished products and thus fiber production in the Asia/Pacific region has grown at a rate of over 12% annually in the past decade.

However, it should be kept in mind that much of the ultimate demand for textiles has remained in Europe and North America. As a result the Asia/Pacific region now exports about 60% of its polyester fiber production, mainly in the form of finished goods, to Europe and the Americas. Textile industry experts expect that Asia will continue to expand its role as a producer and exporter of garments. This is both because Asia's own demand for textiles is growing rapidly and because Asian large, low cost textile and garment manufacturers are well positioned to serve the growing local market as well as to increase their market share of the world trade in textiles and garments. Given this reasoning, several textile experts have projected that polyester fiber production in the Asia/Pacific region will increase from 6.4 Mt in 1993 to 12.8 Mt by 2003. This is far greater, in absolute terms, than the increase projected for any of the other main geographic regions of the world.

Relevance to the Projected Market for Cottonized Fiber Flax

Since pure polyester clothing is sticky, hot and uncomfortable in hot weather, it is expected much of the world's polyester fiber will continue to be used in blends with natural fibers. To date cotton has been the overwhelming choice of a natural fiber to blend with polyester, both because it is available in large quantities and because it is the cheapest natural fiber. However, cottonized flax fiber would offer improved comfort, durability and strength relative to cotton if it were used to the same degree as cotton in a blend. Alternatively an increased percentage of polyester could be used with a correspondingly lower percentage of cottonized flax to give a garment with the same comfort level as a polyester/cotton blended garment. It is predicted that the use of cottonized flax would increase very rapidly if the price of cottonized flax were to drop to a price competitive with cotton and/or if the supply of cottonized flax were large enough that large spinners could be assured that they could make it a regular and large part of the blended polyester production lines. If this were to happen, huge and rapidly growing volume markets would open up in the Asia/Pacific region for the use of cottonized flax as a blending material with polyester.

4.6 Future World Fiber Demand

The future growth in the demand for cottonized flax fibers will be greatly influenced by the demand for other fibers that are used in textiles. Making projections is always risky since unforeseen events such as the development of new technologies can dramatically alter demand and supply relationships. This is especially the case when longer term projections are attempted. With this warning in mind, T.F.N. Johnson of Courtaulds (U.K.) carried out a study in 1996 to project the quantity of man-made fibers that will likely need to be produced by the year 2050 (Textile Asia, August 1996). This study, by default, also provides some interesting insights into the likely demand for natural fibers.

In Johnson's study fibers were divided into three major groups assuming that:

i) long staple fibers (e.g., wool, long acrylic[30]) primarily provide warmth;

ii) cellulosic fibers (e.g., cotton, viscose, flax, etc.) are "hydrophilic" in that they react strongly with moisture. They are used mainly to provide comfort; and

iii) thermoplastic fibers (e.g., polyester, nylon, etc.) are "hydrophobic" in that they do not react strongly with moisture. They supply almost all industrial demand for fiber and supply the balance of apparel and household demand not supplied by the other two groups of fibers.

Johnson first collected data published by Shell that made a long-range population and per capita income projections under a number of scenarios for major economic regions of the world. These projections were then combined with income elasticities for fiber consumption. This produced a base case projection of 130 million tonnes of fiber for textiles being needed by 2050 versus the roughly 47 million tonnes used in 2000. This projected demand was then broken into the three groupings of fibers and projections were made for each group. In the case of long staple "warmth" fibers it was projected that market share will continue to fall because new fiber constructions using synthetic fibers (e.g., fleecewear) has allowed thermoplastic fibers to supply, in many applications, warmth in a cheap and/or more comfortable way than wool. The rise in the use of central heating is also reducing the demand for warmth fibers. This methodology indicates that total wool demand will continue to grow slowly and that acrylic production will grow from the current 2.5 million tonnes to about 6.0 million tonnes by 2050.

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[30] Although long acrylic fibers are made from a thermoplastic, they are constructed in a way that makes them a good substitute for wool in sweaters and socks.

The author then projected the demand for cellulosic fibers after noting that the thermoplastics fiber grouping has taken over most industrial fiber markets that were formerly filled by cellulosic fibers. This led to a projected demand in 2050 for cellulosic or "comfort" fibers of 40-45 million tonnes. The author poses the question, "Can cotton supply the expanding market for hydrophilic short staple fibers?" He points out that the world area under cotton cultivation has been roughly constant for 60 years and that for every new area brought under cotton[31], an area goes out of cotton due to salinity or pest problems. In the past cotton production rose only due to increasing yields. However, over the past decade yields have stopped rising (especially in the US which has some of the highest average yields), due to a variety of reasons, such as pesticide resistance, salinity problems, floods and drought. Perhaps this indicates that the limits of conventional cotton farming technology have been reached. New cotton varieties are being developed using biotechnology (e.g., Bt cotton to reduce insect damage) and these are expected to increase world yields by 5-10%. If the cotton area remains relatively fixed in the future (the author argues that increased demand for grain and livestock products will cancel out any significant expansion in cotton acreage) and yields increase by roughly 10%, then cotton production by 2050 will reach only about 22 million tonnes annually and create a demand for 18 – 23 million tonnes of non-cotton cellulosic fibers. The author suggests that such a large amount of cellulosic fiber can only come from the viscose (e.g., rayon) and lyocell made from wood pulp. No mention is made of the possibility of sourcing flax and hemp. This is probably because the author was unaware of the possibilities of producing large volumes of reasonably priced flax or hemp fibers outside of the traditional locations for souricng these fibers.

The author also considers the case of genetic engineering allowing cotton yields to grow at a slightly faster rate that that experienced from 1950-1990 (i.e., the last period when cotton yields trended upward). Under this scenario cotton production could almost keep up to demand and only about 2.0 million tonnes of non-cotton cellulosic fiber would be needed to top up the demand for comfort fibers. The author then states that at this time it is not possible to pick a most likely figure for cotton production into the 21st century, mainly because of the unknown potential of genetic improvements but the above two scenarios would represent the extremes of what might come to pass.

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[31] Cotton can only be grown in areas where rainfall is minimal or non-existent when the cotton bolls are opening and being picked and where the growing season is relatively long. These two requirements alone severely limit the locations where cotton can be grown.

In summary, unless cotton yields rise dramatically to give cotton production levels above 20-25 million tonnes, the world will need other hydrophilic staple products at a volume of 15-20 million tonnes by 2050. If flax and hemp farmers and processors can organize themselves and carry out the required research and development work to get more consistent and lower cost fibers from flax and hemp, **there is a potential demand for 2-20 million tonnes of such fibers for use in textiles by 2050** based on the findings of the just described study. This demand does not include demand growth for flax and hemp that is likely to occur in the pulp and paper and plastic composite sub-sectors.

5 Personal Absorbent Hygiene Products

5.1 Overview of Higher-End Nonwoven Products

As time goes on, the world of fiber and fiber based products continues to grow in volume and complexity. A prime example of this would be the rapid growth of the nonwoven sub-sector within the fiber sector since the 1950s. A nonwoven fabric can be defined in several different ways. For instance, the Textile Institute defines nonwovens, in general, as:

> *...textile structures made directly from fiber rather than yarn. (nonwoven) fabrics are normally made from continuous filaments or from fiber webs or batts strengthened by bonding, using various techniques: these include adhesive bonding, mechanical interlocking by needling or fluid jet entanglement, thermal bonding and stitch bonding.*

The American Society for Testing and Materials (ASTM D123-96) defines a nonwoven fabric as:

> *A textile structure produced by bonding or interlocking of fibers, or both, accompanied by mechanical, chemical, or solvent means and combinations thereof.*

Nonwoven fabrics[32] are produced in weights ranging from less than 10 gm/m^2 to as much as 3500 gm/m^2 and are sold in the form of rolls (i.e., "roll goods") cut to lengths and width to accommodate the construction of specific end-use products. Nonwovens can be engineered to have appearances, textures and other aesthetic properties comparable to traditional woven knit fabrics and can be constructed to have a very wide range of characteristics and properties.

End-uses for nonwoven roll goods can be grouped into two categories: disposable and durables. In general, disposable product applications account for about 85% of the volume and 60% of the value of nonwoven roll goods consumption. Disposable products include coverstocks, medical/surgical items, wipes filters, envelopes and packaging, industrial and chemical protective apparel, abrasives, fabric softener sheets and detergent packets and other disposables. Durable products include interlinings for clothing; coating and laminating substrates; geotextiles; roofing, building, insulation and other construction materials; furniture and bedding construction sheeting; bedding and other home furnishing fabrics; wall coverings and window treatments; carpet underlays; automotive

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[32] Pulp and paper can be considered special types of nonwovens; thus nonwovens which are not pulp or paper are usually referred to as nonwoven fabrics even though some (e.g., wet wipes) may more closely represent a paper than a fabric.

interior trim, headliners and trunkliners; electronic components; agricultural fabrics and other durables.

With this huge range of end-uses there is certainly a high probability that fibers from flax will eventually be successfully and profitably used in many nonwoven products. However, in this study resources are not available to investigate all the possibilities and problems that could be faced with each of these end-products. Given the mandate of this market study, we will look briefly at the possibilities and problems that would be encountered if flax fibers were used in personal absorbent hygiene products (PAHP), the largest end product market for nonwoven fabrics. This category of products includes disposable baby diapers, training pants, feminine hygiene (e.g., sanitary napkins and tampons), and adult incontinence products. These new consumer items evolved over the last 50 years as the product development divisions of companies searched for easy, cheap and convenient ways to deal with problems caused when people (from babies to old folks) urinate and defecate when not in and/or on toilet-like device or structures. They also deal with the leakage problems women experience when menstrual fluids flow out of their bodies. For many decades, such problems were generally dealt with by the use of diapers and pads made from woven fabrics. However, since 1960, PAHP have been increasingly used in countries whose citizens are wealthy enough to afford the convenience offered by PAHP. These PAHP are constructed, in part, with absorbent fibers like wood fluff and cotton. Flax fibers are generally more absorbent than wood fluff and cotton and hence could theoretically be used in the construction of such products. The following sections of this report will look briefly at the size of the existing market for PAHP and the parameters that are affecting changes in the type of PAHP that are made, the materials that are used and the promise and problems that flax fibers might experience if they were to be used in PAHP.

5.2 Market Considerations

In 1997 in North America the value of the nonwovens roll goods market at the factory door was estimated to be US$2.8 billion with 68% of this total being roll goods destined for disposable applications. About 24% of the value of these disposable applications was for coverstock. Most of the coverstock that is made is used to form the outer cover or layer of personal absorbent hygiene products. Once these products are formed (generally by combining coverstock, wood fluff, super absorbent polymers and fastening structures) and sold at the retail or institutional level, they will generate roughly US$10 billion of sales in the US and about US$30 billion worldwide[33].

The PAHP market, especially in developed countries, has evolved into an industry that is characterized by:

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[33] Batra et. al. (1992) and INDA (1998).

1) Complicated technologies;

2) Large volume, high speed production lines;

3) Fast technological and market changes;

4) High capital intensity;

5) Very competitive market strategies;

6) Mature, slowly growing home markets; and

7) A global outlook.

In this regard, markets in the US, Canada, Western Europe and Japan are considered the major mature markets while those in China, India, South America and Mexico are considered to be the most promising emerging markets.

Statistics on the various market segments in the disposables area have been estimated from a variety of sources and are, to a certain extent, confidential, however, the following numbers will give an indication of the magnitudes involved.

Table 5.2.1 - Estimated world disposables market

(000 tonnes)

	1998	Projected 2003
USA & Canada	600	740
Japan	120	170
Western Europe	480	630
Rest of World	240	440
Total	1,440	1,980

Source Derived from unpublished data based on MTS (1999).

Table 5.2.2 - Estimated breakdown of disposables demand in major developed countries

	1998 Volume	Sanitary Facings	Medical/ Surgical	Filtration	Other
			('000 tonnes)		
USA & Canada	600	320	140	40	90
Japan	120	30	30	40	20
Western Europe	480	270	40	60	110
			%		
USA & Canada	100%	54	24	7	15
Japan	100%	25	27	30	18
Western Europe	100%	56	9	12	23

Source: Derived from unpublished data based on MTS (1999).

NOTE: In the above table, the coverstock used in disposable diapers, tampons and pads, would fall under the category labeled "Sanitary Facings". The volumes shown do not include the wood fluff and other items that are needed to produce a consumer ready PAHP.

Table 5.2.3 - Estimated retail sales in USA (1998)

Item	$000,000	Units (Billions)
Diapers	4,015	17.7
Training Pants	690	1.6
Pads/Tampons	2,280	20.0
Adult Incontinence a/	620	1.6
Total	7,605	-

a/ includes retail sales only (i.e., institutional sales are excluded)

Source: Kimberley-Clark (2000).

5.3 Product Construction Considerations

A basic PAHP consists of cheap but effective combinations of products which can be easily worn around the waist of the body and/or between the crotch. It must be made of materials which can quickly absorb a liquid, semi-solid or solid discharge (called an "insult" by R&D people who work in this area) without allowing it to leak out onto the upper or lower body or to the surrounding environment. The PAHP must be cheap enough that after one to three insults, it can be changed and disposed of in the garbage without causing undue financial hardship on the user or the custodian of the user. The construction of PAHP has become increasingly high speed and complex. The components that make up a basic PAHP are described in the following paragraphs.

When PAHP are designed the two over-riding concerns from the users point of view are discomfort and leakage. A PAHP which feels rough, gritty and/or wet, clammy or sticky will not have a great future as a commercial product. Similarly a PAHP which is bulky, stiff, noisy or causes skin irritation or skin rashes will not be commercially acceptable. Thus a potential PAHP must not cause discomfort for the user. However, perhaps, equally important, a PAHP must never allow leakage. This means that designers of PAHP must be concerned with:

1) rapid entry of liquid through coverstock;

2) rapid dispersal of liquid in the absorbent;

3) a high retention rate of liquid under pressure;

4) prevention of reverse flow of liquid through coverstock;

5) waterproof backing; and

6) elastic waist and legs which are tight but not uncomfortable.

The shaping and sizing of PAHP continues to evolve over time as designers and manufacturers strive to find new combinations that will allow them to gain a market advantage either in the area of improved product characteristics (perceived or actual) and/or reduced production costs (and hence the ability to cut selling price). Such improvements or pseudo-improvements are often heavily promoted in the media in an attempt to gain market share. Thus, in recent years, there are few people in North America who have not heard of tampons with "wings" or new ultra thin "pampers".

Companies producing PAHP have R&D labs which are continually considering new combinations of fibers, films, and chemical products and treatments that will improve the "bottom line" of the firm in question but the tentative recipes for new or improved PAHP must ultimately meet the commercial and mechanical requirements for large scale, automated production. Production methods range greatly around the world but in developed countries, the largest volume of production takes place in capital intensive, automated, large scale, and continuous production lines. The following list shows the possible steps that might be involved in such a production line (note: not all steps may be included and they may not be in the order shown on this list):

1) pulp-bale opening;

2) fibrizing, in a hammer or pin mill;

3) forming a fluff batt (often by air-layering in a forming chamber with a vacuum floor screen);

4) adding SAP (by screw feed, spray or roller feed);

5) powder-printing or scatter-coating;

6) folding fluff batts;

7) embossing;

8) heat treatment;

9) laying tissue, coverstock, anti-wet-back sheet and backsheet;

10) cutting to shape, with rotary knives, dies in water jets;

11) applying adhesive between backsheet or batt and between coverstock and batt;

12) applying elastic on edge of leg and waist openings;

13) heat sealing

14) applying fastening devices and waistband barrier strip; and

15) folding and packaging completed diaper, tampon or pad.

There are several factors that affect machine speed, efficiency and hence, unit production costs. For instance, the distribution of the SAP is important. A homogeneous mix of fluff and granules[34] is easy to achieve by air-mixing in a forming chamber but this has several disadvantages. Some SAP is wasted in non-target areas, knives and dies are dulled when cutting through SAP and/or water jets cutters become clogged with swollen gel. Any of these occurrences will increase the cost and/or reduce unit throughput. Similarly the application and positioning of elastic strips is very important to prevent leakage but commercial diaper lines often run so that the waistband direction is running at right angles to the movement of the rest of the product moving in the line. This, in turn, constrains the speed of the line. However, in spite of these type of constraints, the PAHP industry is continually developing new mechanical systems that can cope with new materials and construction techniques.

The commercial will to modify and/or develop new lines is normally driven by the perception that it will, in some manner, improve the profit status of the company. This, in turn, is usually driven by discoveries and/or tests in the lab or in the consumer market place.

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[34] The purpose of these granules and fluff is described later in this Chapter.

When a potential new fiber, film, fabric, or chemical product is being considered for use in a PAHP, it must pass through a variety of hurtles, both commercial and technical. The commercial ones revolve around raw material supply, price and consistency or properties (e.g., Is the raw material readily available at stable prices? Is the raw material consistent in quality attributes or can it be blended to give consistent attributes? Etc.). The technical hurtles revolve around being able to show significant superiority in one or more technical parameters before it will be considered for use in a pure or blended form. Such parameters would include the following:

1) **Wicking Rate**

   This can be defined as the rate at which a liquid "front" advances through a material. The movement of such a front is often measured both vertically and horizontally.

2) **Absorption Rate**

   This can be defined as the rate at which liquid enters a material. It is measured both under "conditions of demand" and under conditions whereby the rate of supply of liquid is greater than the rate of absorption and the excess liquid runs off.

3) **Absorbent Capacity**

   This is defined as the amount of liquid that can be held by a material under specific conditions, and this includes the liquid absorbed by the material itself as well as that in the void spaces.

4) **Wettability**

   Materials are often ranked for wettability by comparing:

   i) wetting time (the time taken for a drop of liquid to be absorbed by a material)

   ii) sinking time (the time taken for a specimen to lose the bouyancy given by surface–tension effects); and

   iii) "contact angle" at the air/liquid/solid boundary.

5) Permeability

This refers to the amount of liquid that can pass through a material under specific conditions or, conversely, the time for a specific amount of liquid to pass through the material. Permeability tests can consider:

i) the hydrostatic pressure created during the penetration of a material by a liquid;

ii) the time needed for a given volume of liquid to pass through a material; and

iii) the volume of liquid that passes through a material in a given time.

5.3.1 Absorbents

The materials used in the absorbent layer of a disposable diaper or tampon has been normally "fluff pulp" from wood pulp or other cellulose based fibers (e.g., cotton). This is because cellulosic fibers can easily absorb moisture but are rigid enough to allow liquid to "flow through" and past moisture saturated fibers to come in contact with fibers that are still dry. Fluff pulp is normally used instead of cotton or other cellulosic based fibers because it is cheaper than cotton and is available in large, consistent quantities at quite stable prices.

Fluff pulp is made from wood in much the same way as paper pulp is made from wood, however, in the case of paper pulp, the cellulosic fibers are collected on a fine screen and then rolled and dried to produce thick sheets of rough paper (i.e., paper pulp). Whereas when wood fluff is made, the fibers are mixed with a "debonding" chemical so they dry in a loose dried "unbonded" form. After drying, the loose fibers are then pressed into bales or into a roll form to minimize shipping costs to PAHP production facilities.

The absorbency of fluff pulp depends on both the type of tree from which it originates and the method of manufacture. Desirable properties of wood pulp would include:

- high absorption capacity;
- high absorption rate;
- easy wetability (i.e., low contact angle);

- softness;
- whiteness;
- web strength (important when preparing the fibers); and
- resistance to aging.

Some of the parameters that control these properties are:

- fiber length (long fibers give good "runnability" in a diaper but short fibers give softness);
- fiber stiffness (stiff fibers give good absorption capacity);
- lignin (high lignin control improves stiffness but it also reduces whiteness);
- resins and extractives (resin reduces wetability and also encourages aging);
- hemicellulose (low hemicellulose content is beneficial to increase absorbency); and
- chemical finish (debonders are used to decrease the tendency of cellulosic fibers to mat together but they, as a consequence, reduce wetability).

Trees can be classified as hardwood (broad-leaved) or softwood (usually but not always coniferous). Most fluff pulp is manufactured from softwoods which have fibers more suited to the characteristics needed for PAHP. If hardwood and softwood are compared (see Table 5.3.1), it can be seen that softwood fibers are generally longer, thicker and contain more lignin than hardwoods.

Table 5.3.1 - Comparison of softwood and hardwood fibers

Property	Softwood	Hardwood
Fiber length	3-5 mm	1-3 mm
Fiber diameter	20-40 µm	20-30 µm
Wall thickness	2-8 µm	3-7 µm
Cellulose %	40-25	40-45
Hemicellulose %	28	35
Lignin %	25-34	16-23

Source: The Textile Institute

In its natural form, wood consists of fibers adhering to each other to give a solid (i.e., wood) that can be subsequently torn apart (i.e., mechanically pulped) or by dissolving the adhesives holding the fibers together (i.e., chemical pulping). Wood fibers are primarily made of cellulose and hemicellulose, the adhesive is made of lignin and there may be resins present. Mechanical pulping retains all the lignin and hence is known as "high-yield" pulping since it gives a yield of over 90%. In contrast, chemical puling removes almost all the lignin and even some of the hemicellulose and cellulose and gives a yield of only 40-60%. Chemical pulps are more expensive to produce, however, they tend to have longer, whiter, and softer fibers than mechanically pulped fibers. There are different methods of chemical pulping and each has advantages and disadvantages (e.g., the "sulphite process", a commonly used chemical pulping system, does not remove the wood resins and consequently pulp form the sulphite process is seldom used for fluff). Commercially wood fluff is often made from a blend of mechanical and chemical pulps to optimize the performance/cost trade-off.

After the pulping process, almost all cellulosic fibers used in PAHP are bleached. Although health regulations do not require that such bleaching be done, consumers have generally come to believe that a white fiber is a clean fiber which is germ-free. This may not be true but perceptions have a tremendous influence on the type and brand of PAHP that is purchased. Hence until a public awareness or advertising campaign is launched which points out that PAHP fibers need not be white to be safe and effective, it is likely that almost all fibers used in PAHP will be bleached.

After bleaching, the wood pulp is formed into a sheet and some of the water is removed by means of press rollers, but less pressure is used for fluff pulp than for papermaking pulp. At this stage, hydrogen bonds form between the fibers, so a cationic debonding agent is be added before sheet formation to prevent bonds form forming and thus give a easily fluffed product. However, debonders have a disadvantage in that they reduce wettability and may cause skin irritation in certain PAHP. (Mechanical pulps do not need debonders). The sheet is then dried to a moisture content of 6-7% before being put into a roll or bale from for shipment. This material is then "fluffed" during the first stage of a continuous PAHPS production line. Fiber in a continuous roll is easier and cheaper to feed into a continuous processing machine but fibers in a bale form are a better choice when blending and mixing of fibers must be done before the fibers are used.

Production systems for PAHP are normally large scale, highly automated and have almost unbelievably high throughput (e.g., 300-400 diapers/minute). This gives producers very low costs of production with relatively little labor cost but such systems depend on having large quantities of consistent quality fiber available at all times. To date, fluff pulp and synthetic fibers have been far more successful in meeting this need than has cotton and hence only a few PAHP are based on cotton fibers (e.g., Kotex brand tampons).

Market research and experience has also shown that the fibers used in PAHP must be perceived by consumers to be clean and "free from germs". Visually this means that most consumers expect the fibers in PAHP to be white. This, in turn, means that fibers in PAHP are normally bleached. In the case of pulp fluff this happens during the production process; in the case of cotton or synthetic fibers bleaching is usually done before the fiber enters the PAHP production facility.

The ability of a mat of fibers to absorb liquids is affected, to a large extent, by the intrinsic properties of the fiber (e.g., chemical make-up of the fiber, thickness of cell wall, size of lumen) and by the packaging density of the fibers. The more tightly the fibers are packed, the smaller is the average pore size and stronger the effect of capillary forces which draw moisture away. However, if fibers are too densely packed the liquid "flow-through rate" is reduced because of the high number of fiber-crossing points in the fiber matrix. In modern PAHP production processes it is common to alter the density of the fiber depending on the type, location and duration of liquid insults that are expected to occur. In theory, there are many physical configurations and blends of fibers that could be used to reach a given set of end-use requirements. The exact combinations that are chosen for large scale, high speed commercial production are generally those that appear to meet not only the physical requirements for the end-use in question but also that meet such commercial requirements as:

1) stable and low cost;
2) available in large consistent quantities;
3) long storage and shelf life;
4) easy to blend and meter; and
5) secure sources of supply.

Fibers from flax could, in theory, be used as an absorbent in PAHP. The issues and problems that survived this possibility will be discussed in Section 5.4.

5.3.2 Super Absorbency Polymers

In the last few decades, chemists have developed a range of polymers that can absorb 70 times or more their own weight of urine. These are often referred to as Super Absorbency Polymers or SAP. The development of SAP has had an almost revolutionary impact on reducing the weight and bulk of PAHP. Such SAP are also often referred to as **hydrogels** because they go from a solid (usually in the form of a tiny bead, a powder or a film) to a swollen gel shape in the presence of water or urine. A hydrogel particle, after absorbing water, is many times its original size, but retains its original shape and does not dissolve.

The main types of hydrogels are polyacrylates, starch-based graft copolymers, cellulose-based graft copolymers, carboxymethyl cellulose, polymaleic anhydride and cross-linked natural gums. Polyacrylates are one of the most popular types. Starch and cellulose-based hydrogels are prone to heat and chemical degradation but there is a good market for the attach-based types if they can be produced cheaply when starch sources (e.g., potatoes, cereal grains) are cheap. Manufacturers can produce SAP in the form of grains, powders, flakes, sheets or fibers. They can also be coated on the core of another polymer. Particle size and shape are important because they affect the absorption rate and the ease of handling, metering and manufacturing (e.g., powders below 30 microns in diameter are an industrial safety hazard while grains with a diameter more than 4 millimeters give a gritty feel to products containing them).

The use of hydrogels in PAHP began in the 1960s, however, in the late 1970s, the use of hydrogels in tampons was suspected of being the cause of something called Toxic Shock Syndrome. However, it took until 1985 before the cause and effect were clarified and it was shown that hydrogels disturb the balance of magnesium in the vagina, which, in turn, induced normally harmless bacteria to produce large amounts of toxin. This research also showed that no toxic effects were produced by hydrogels as long as they were not used in products actually worn internally.

Hydrogels are almost always used in combinations with other materials in PAHP because:

i) they do not wick aqueous liquids because the polymer surface is not sufficiently wettable, so another component is needed to assist in the transport of liquid to the SAP particles;

ii) the gel is flexible and if the particles swell and touch each other they block the flow of liquid to still dry particles. Placing the grains sufficiently apart and fixing them in place within a matrix of fibers can prevent such “gel-blocking”. In other words, the gel needs room to expand and a matrix of fibers around the gel particles can produce the necessary void volume;

iii) Although hydrogels can absorb relatively huge amounts of liquid, they cannot absorb rapid insults of urine as quickly as fibers can. Hence, a matrix of absorbent fibers is still necessary to cope with the rapid inflow of liquid and then to temporarily hold and transport the liquid to the hydrogel particles which will ultimately absorb and hold most of the liquid.

Needless to say flax fibers or any other cellulosic fibers are not direct substitutes for chemicals like SAP; however, in modern PAHP, cellulosic fibers are always used in conjunction with SAP.

5.3.3 Other Materials

Coverstock

The coverstock refers to the material which comes in direct contact with the skin of the user. In addition to being cheap enough to be disposable, a coverstock must be smooth, flexible, comfortable to the touch and allow the rapid transmission of liquid. It has been accepted in the industry that a coverstock should also prevent the leakage of liquid back onto the skin from a wet PAHP or at least should have a "dry feel". Coverstocks do not necessarily have to absorb liquid; they do, however, have to allow liquid to quickly pass through them. Coverstocks can be produced from staple fibers (i.e., 2 to 4 cm in length), continuous filaments or films and range in density from 5 to 30 gm/m^2 (NOTE: average woven shirt fabric would be 180 – 250 gm/ m^2 so coverstock is like a film rather than a fabric). Coverstocks are almost never woven but, are produced as "nonwoven fabrics" to reduce the cost.

The main fibers used in disposable coverstocks are viscose (i.e., from wood fibers), polyester (PET), polypropylene (PP), polyethylene (PE) or bicomponent fibers formed by combining two of these fibers. At one time viscose was popular but now 100% PP or blends are usually used. Cotton or wood fibers are seldom, if ever, used now for coverstock since they would absorb liquid and hold it next to the skin and hence give the person wearing the product a "wet feel" as soon as a liquid of fecal matter insult occurred. Using flax fibers, even cottonized ones, would lead to similar problems of "wet feel" and hence it is unlikely that flax fibers of any sort would be accepted in the coverstock market.

Elastic and Tab Materials

One of the most expensive materials, in the manufacture of disposable incontinence products are the elastic and tab materials used to keep the product snugly fitted around the waist and legs. The tension must be sufficient so that physical leakage does not occur but loose enough so that chaffing does not occur. In addition, the elastic and tabs must be fastened to the coverstock-absorbency layer-coverstock-sandwich of materials in a way that is secure and long–lasting yet still allows 300 – 400 diapers per minute to be produced in a disposable diaper line. Needless to say, it is highly unlikely that flax fibers would be used in any part of the material used for elastic or tabs.

6 Possibilities for Saskatchewan

6.1 The Present Situation

The Saskatchewan farm economy continues to experience boom and bust cycles with net farm incomes trending downward over the last decade. Farmers, government officials, business leaders and academics are continuously searching for ways to add value to Saskatchewan's raw agricultural production to help raise net incomes in rural areas. In this regard, the production of fiber from flax offers some great long run opportunities.

6.1.1 Problems Constraining Demand for Cottonized Flax

In Chapter 2 of this report we showed that, at the present time, the existing market for cottonized flax is very much a market for a niche or novelty fiber. This is not because the intrinsic properties of cottonized flax are poor; rather it is because the price is relatively high, the price fluctuates too much, physical properties are too inconsistent, and supply is very limited. According to survey results reported in Chapter 2, existing and potential users have stated that they would use much larger quantities of cottonized flax if these problems can be resolved. This seems to be confirmed in Chapter 4 where we looked briefly at fibers which are compliments and substitutes for cottonized flax and at projections for the growth in future demand for "comfort fibers" like cottonized flax. Cottonized flax could certainly fill part of this demand if the previously listed major problems are overcome.

In Chapter 2 we looked at the likelihood of overcoming these problems. The following is a brief summary of what was shown or illustrated.

1) The price is relatively high

- Cottonized flax can be from 20% to 200% higher in price than cotton.
- The demand for cottonized flax is, to date, still very much driven by fashion.
- Almost all cottonized flax is presently produced using mechanical systems which are relatively inefficient at splitting naturally occurring flax fiber bundles into fibers which are similar to cotton in length and width; this makes it expensive to produce large lots of cottonized flax that have length and width properties consistent with cotton.

- This problem can be largely overcome with further development of non-mechanical technologies to cottonize flax.

2) The price fluctuates too much

- It is not uncommon for the price of a given quality of cottonized flax to vary by 100% within a year.

- There are a very limited number of plants worldwide that can produce cottonized flax. In the short term, production cannot be increased beyond three shifts in 24 hours when fashion dictates a strong demand for cottonized flax. In the past rapidly rising prices were the only way to ration the available supply among end-users when demand shot up due to a change in fashion.

- This problem will be largely overcome when the use of cottonized flax becomes less dependent on fashion needs (i.e., when prices fall and become more stable) and when more production capacity comes on stream and larger and more stable quantities of flax tow become available.

3) The physical properties are inconsistent

- The mechanical cottonization of flax fibers is a relatively inefficient method to separate the naturally occurring flax bundles into a large quantity of fibers with similar length and width dimensions. The result is a wide range of length and width distributions. This makes it very difficult for large scale spinners to use cottonized flax because their production systems are set up to only handle large lots of fibers that have consistent qualities.

- Having large lots of consistent quality flax tow would help cottonizers improve the consistency of their cottonized flax no matter what cottonizing system is used.

- It will be very difficult to produce cottonized flax cheaply and produce it with very consistent quality if mechanical cottonizing systems continue to be used.

- Quite rapid advances are now being made in alternate methods to cottonize flax. These include the use of enzymes, steam explosion and ultra-sound. Costs of these technologies are being significantly reduced and, by their very nature, they have the potential to produce cottonized flax fibers which are cheaper and will have much more consistent fiber length and width dimensions than mechanical cottonizing.

- This problem will be greatly diminished when non-mechanical cottonizing technologies become commercialized.

4) The supply of cottonized flax is very limited

- This problem is directly related to the above three problems. Supply is limited because there are relatively few production facilities. There are relatively few facilities because there is relatively little demand. There is relatively little demand because the cottonized flax fiber produced with the mechanical cottonizing systems in present use is costly to produce because of the relative inefficiency of mechanical systems.

- This problem will be overcome as the three above mentioned problems are overcome.

6.1.2 Potential Supply

In Chapter 2 and 3 we estimated that the demand for cottonized flax could easily double or triple from its present volume of 40-100,000 tonnes if the price were not more than 25% higher than the price of cotton and that volume demanded could easily be one or two million tonnes if the price of cottonized flax were 50% of the price of cotton. After making allowances for marketing and selling margins at different volume levels, this worked out to target price of US$1,330 and US$660 respectively. We then calculated the amount that could be spent on processing and on raw materials (i.e., clean flax tow) under different cost scenarios so that the total cost of cottonized flax is equal to either US$1,330 or US$660. These calculations gave us a range of clean tow prices that "new technology cottonizers" could afford to pay. Several very conservative estimates of tow cleaning costs[35] were then made and used to calculate the cost of producing clean flax tow under different scenarios of straw collection costs, fiber contents, farmer straw incentive payments and tow cleaning costs. These scenarios showed that there were many cost combinations that would allow a non-mechanical cottonizer to produce cottonized fiber for the target cost of US$1,330 and still pay an attractive price for clean tow. There were also cost combinations that would allow a non-mechanical cottonizer to meet the price target of US$660 but the number of possibilities were naturally much more limited than at higher prices.

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[35] For instance we did not assume any revenue from the sale of shives and we assumed we were using the most expensive European tow cleaning systems.

Following this, we estimated the range of seed and straw yields that would be typically produced in Saskatchewan if either oilseed flax or fiber flax varieties were grown. We then compared the farmer gross margins that would be obtained with different combinations of prices for seed and straw and how this would impact on the cost of fiber to a clean tow processor. The results basically showed that for lower value end-uses where quality requirements are not very high or "tight" the cheapest and/or least risky combinations would generally involving salvaging oilseed flax. However for higher value end users where quality and consistency of properties are more important, the desired quantity and quality of desired fiber attributes may not be forthcoming unless a significant straw incentive is paid. Such incentives are only cost effective if the fiber content of the straw is high and this is likely to only happen if fiber varieties or "dual purpose" varieties are grown.

When we compared these farm production scenarios with the clean tow scenarios we were able to show that both oilseed and fiber flax varieties (depending on what quality is needed) have the possibility of producing fiber at a cost low enough to permit clean tow to be produced within the target selling range and yet give farmers gross margins that would often be better than from growing alternative crops.

Thus, in theory, Saskatchewan does have the physical and cost structure potential to become a major producer of cottonized flax within the next ten years if we dedicate R&D and investment dollars to capture this opportunity.

6.1.3 Problems Constraining the Use of Flax Fibers in Personal Absorbent Hygiene Products

In Chapter 5 we looked briefly at the nonwoven fiber sector and particularly at the possibility of using flax fibers in personal absorbent hygiene products (PAHP), the single largest end-use category of nonwovens. Unfortunately the PAHP sector is characterized, for the most part, by a few dominant companies with huge facilities that make up to 400 diapers a minute. These plants operate around the clock and work on the principle of high volumes and low unit margins. To do this they must rely on a supply of highly consistent, readily available wood pulp fluff from pulp mills to make up the fiber portion of the absorbent core of their products. The present flax fiber industry is neither large enough, cheap enough, and/or sophisticated enough at this time to supply fiber to this market.

Flax fibers do, however, appear to have a number of characteristics that may provide technical and/or cost advantages to manufacturers of PAHP. These possibilities need to be investigated further so that flax fibers can be used in PAHP once the flax fiber industry has overcome some of the commercial hurdles mentioned above that have stopped its use, to date, in PAHP.

6.2 SWOT analysis of Possibilities of Saskatchewan to Expand into Cottonized Flax and PAHP Markets

The following headings are another way to help summarize material and ideas presented in this report.

Strengths

- Saskatchewan has huge areas of relatively cheap land that are suited to growing oilseed and fiber flax varieties.
- Fields in Saskatchewan are relatively large and farmed with large machinery. This makes it easier to produce large lots of consistent quality fiber.
- Costs for labor, fuel, electricity, building materials and taxes are lower in Saskatchewan than in France and Belgium, the world's major source of exportable flax fibers.
- Flax straw can be retted in Saskatchewan providing certain sequences of field operations are carried out and farmers have enough financial incentive to carry out these procedures.
- When fiber flax varieties from Europe are grown in Saskatchewan the straw yield and fiber content are similar to those experienced in Europe.
- Oilseed flax straw can be obtained quite cheaply from farmers since the only alternative for most farmers is to burn it.
- The cost of propagating flax seed for planting is cheaper here than in Europe because land costs are much lower but seed yields are roughly the same.

Weaknesses

- Saskatchewan farmers, processors and research personnel have little ability or experience in deliberately producing fiber from flax.
- There are almost no facilities in Saskatchewan that can be used to test the properties of flax fibers. Without standard testing facilities and procedures, it is difficult to quantify how different

production and processing treatments affect the quantity and quality of fiber produced. It also hinders effective buying of flax straw and blending and selling of flax fibers.

- All potential users of cottonized flax are at least 1,500 miles from Saskatchewan and most are overseas. This means that flax tow or cottonized flax must be shipped long distances to end-users.

- The flax fiber sector is much too small and unsophisticated at this time to meet the stringent commercial demands for raw fiber by manufacturers of personal absorbent hygiene products (PAHP).

- There is, at present, only one commercial processor of flax tow in the province. More firms and more plants are needed to capture the opportunities that exist but each plant could cost one to five million dollars. It may be difficult to find investors willing to put money into an industry that is in its early development stage.

- Western Canadians have grown up with a mentality that the only valuable things that can be produced from agriculture here are animal products or seeds of plants. Hence, in general, we do not realize the vast array of fiber based industries that exist in both the developed and under-developed economies of the world. This mentality makes it difficult to access the R&D and investment necessary to capture the added value potential of flax fibers.

Opportunities

- Farmers can physically grow and ret both oilseed flax and fiber flax in the province if they have the incentive to do so.

- Longer term trends and comments of existing and potential users of cottonized flax indicate that cottonized flax consumption could reach levels of over one to two million tonnes annually (i.e., 20 to 40 times current consumption) if prices of cottonized flax become more stable, fall to levels below that of cotton and if the quality of the fiber becomes more consistent.

- Continuing advances in cottonizing technologies that use enzymes, steam explosion and ultra-sound all offer the possibility of significantly reducing the cost of cottonizing flax relative to traditional mechanical cottonizing systems because the yield of commercially salable fibers using these new technologies is much higher than with mechanical cottonizing systems.

- European farmers could not afford to produce only flax tow because of their much higher land costs; Saskatchewan farmers could.

- The cottonized flax industry will not grow unless it has cheaper methods to produce more consistent quality fiber (i.e., unless it moves away from mechanical cottonization) and a large, stable and relatively cheap source of good quality flax tow. With investments in R&D and processing facilities, Saskatchewan could become such a supplier of flax tow.

- Whether we grow flax for seed or fiber, the major markets of these products are, for the most part, overseas. Cottonized flax and even good quality flax tow are more valuable on a kilo or volume basis than flax seed for crushing. Thus the high cost of freight from Saskatchewan is relatively less burdensome when cottonized flax or good quality flax tow are shipped.

- The production of flax fibers is much less chemical intensive than the production of cotton or wood fibers. This fact could be exploited when marketing to environmentally conscientious processors and consumers.

- Cleaning flax tow and cottonizing flax do not require cheap labor to be profitable and hence could easily be cost competitively done in Saskatchewan.

- The production of 10,000 acres of oilseed flax for crushing purposes may, at most, generate in Canada one half time job if we add all the hours spent by the truckers, elevator agents, railway workers and terminal elevator operators. In France, if fiber flax is grown on 10,000 acres of land and the resulting long line, flax tow, seed, shives and cottonized flax are produced in reasonably automated facilities, about 100 full time jobs are created. In Saskatchewan if a plant only cleaned the tow and then produced cottonized flax from 10,000 acres of fiber flax we could conservatively expect 10-30 full time jobs to be created. If the straw came from salvaged oilseed straw, the job creation potential per acre would be much less because the fiber yield per acre is much less, however, the jobs created would still be much greater than if only seed were produced and the straw burnt.

- The agricultural research establishment on the Prairies has taken a number of market opportunities in the past and developed them into world scale export crops (e.g., canola, lentils, field peas, canary seed, chickpeas). Cottonized flax and flax fibers, in general, offer such a market opportunity now.

Threats

- Other areas of the world that have soils and climate suitable for flax growing, cheap land and existing fiber processing facilities (e.g., Russia, China, Europe) could expand flax tow and cottonized flax production. This could include areas in North America that have not grown flax for many years but could do so in the future (e.g., Quebec, South Carolina, Texas, Oregon, etc.)

- Governments and/or private companies in new or existing flax production regions could develop their flax fiber based industries much faster than Saskatchewan, if they launch dedicated flax fiber R&D programs.

- Cotton or synthetic fiber research could find ways to produce the same appearance and comfort of cottonized flax fiber blended fabrics at prices cheaper than by the incorporation of cottonized flax in the blend.

- Existing fiber flax producers get over 80% of their income from producing long line fibers. In the immediate future they may be willing and able to "dump" flax tow on the market, in the short run, to discourage the production of flax tow from non-traditional flax fiber producing regions like Saskatchewan.

- R&D work with hemp and jute may allow farmers and processors of these crops to produce cottonized fibers that are as cost competitive and ecologically friendly as cottonized flax fibers.

6.3 The Future

6.3.1 Quality and Quantity Parameters for Processing Plants

If the flax fiber industry is to develop, many more processing plants will have to be built. Such plants will, at the minimum, process flax straw into clean flax fibers and shives. Some may also eventually cottonize flax and/or turn clean tow into combed sliver ready for spinning. Still others may blend flax fibers with plastic fibers and form nonwoven mats for use in plastic composites or blend with hemp fibers to produce insulation, packaging and filtration materials. It is too early to say what the minimum quality of fibers should be for many of these purposes or what the minimum economic size of plant will be. Technology is still evolving in the field of processing and utilizing flax fibers so the minimum acceptable size of a plant now may be quite different in a few years time. Many tow cleaning systems in Western Europe can turn about 1.5 tonnes of partly clean tow with 30-50% shives into clean tow with less than 5% shives in one hour. This should probably be considered the minimum capacity for any new processing plants that are built.

In terms of quality, the range of possibilities for clean tow (i.e., with less than 5% shives) is quite wide since we are dealing with a natural fiber whose properties can be influenced greatly by the natural environment and how it is grown and processed. What is important for the long term growth of the industry is that standard methods be developed to test the properties of the flax straw and tow that are important to the processors and end users of the tow. This will not only facilitate the fair and equitable purchase and sales of straw and tow; it will also facilitate blending to produce more homogeneous lots and encourage agronomic and processing practices that produce the type of straw and tow that is desired by the market place.

In the case of cottonized flax, the producer of cottonized flax will be rewarded relatively more for fibers that are pressed into bales the same size as those of cotton and that have dimensional properties similar to cotton (i.e., the same fiber length distributions, fiber fineness, trash content).

6.3.2 Value Added and Job Creation Potential

Flax fibers can be used in a wide range of end products. In this study we considered only two major potential end-uses for clean, medium length flax fiber for higher-end uses. These end uses were cottonized flax and PAHP. At this time, it is unlikely the producers of PAHP will use flax fibers in their products so we will ignore this potential in our value-added potential estimates.

In Chapter 3 we estimated the variable costs of producing an oilseed flax crop to be roughly $100/acre and the gross margin to be between $40-110/acre. Most of the seed produced from oilseed flax is exported as seed and hence little value[36] is added and few jobs are created between the farm gate and the port. If the oilseed straw is gathered and processed into semi-clean tow, it will generate, very conservatively, 100 kilos of tow per acre[37]. By the time this tow reaches a Canadian port it should be worth $400-800 per tonne or $40-80/acre. Thus from every 1,000 tonnes of flax tow demand, we can produce $400,000-800,000 of added value to the straw[38]. If we took the clean tow produced from oilseed flax, we should get a cottonized fiber yield of at least 70% based on non-mechanical cottonizing systems. If this were exported at the high cottonized flax target price of US$1,330 it would be worth roughly C$1,900 at the port.

If we were to use fiber flax we would probably harvest 10 bushels of seed per acre (i.e., 0.250 tonnes/acre) instead of the 25 bushels (i.e., 0.625 tonnes/acre) of seed that we could expect with oilseed flax. However fiber flax should give us about 850 kilos of clean tow/acre. If this tow were subsequently cottonized, the yield of cottonized flax should be at least 80% based on non-mechanical cottonizing systems. (The yield of cottonized flax from fiber flax tow should be somewhat higher than from oilseed flax because we are assuming farmers get significant straw incentives to grow fiber flax and hence the straw and resultant tow is more consistent in dimensions and has better fiber division).

Based on rough ratios of tonnes processed and full time jobs in flax processing plants in France, Belgium and Quebec, we could also estimate that one full time equivalent job will be created for every 1,000-1,500 tonnes of clean flax tow that is produced and at least two more jobs for every 1,000 tonnes of cottonized flax produced.

From the above described assumptions and numbers we were able to create Table 6.3.1. This table presents a quick way of summarizing the export value, the value added and job potential of producing cottonized flax. The reader could argue over any of the numbers in this table and say that it is too high or too low. This could be true since the numbers were greatly simplified to present a broad overview of the economic opportunity presented by producing cottonized flax.

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[36] Value added activities would include transport, grading, cleaning, blending and possibly bagging.

[37] This is based on the assumption of 0.5 tonnes of straw at 20% fiber content.

[38] Value added activities would include baling, hauling, stacking, cleaning, grading, blending, re-baling and further transport.

Table 6.3.1 – Exports; value added and job creation potential from producing cottonized flax from 100,000 acres in Saskatchewan /a

	Oilseed Flax (Straw Burnt)	Oilseed Flax (Straw Salvaged)	Fiber Flax (use straw and seed)
Seed Produced (tonnes)	62,500	62,500	25,000
Export Selling Price of Seed ($/tonne)	340	340	340
Gross Export Value ($'000)	21,250	21,250	8,500
Cottonized Flax Produced (tonnes) /b	-	7,000	68,000
Export Selling Price of Cottonized Flax ($/tonne)	-	1,900	1,900
Gross Export Value ($'000)	-	13,300	129,200
Seed & Fiber Export Value ($'000)	21,250	34,550	137,700
Farm Variable Costs ($'000) /c	10,000	10,000	20,000
Value Added After Deducting Farm Variable Costs ($'000)	11,250	24,550	117,700
Jobs Created /d	5	26	206

NOTE: All values are rough approximates made to simplify presentation of this table.

a/ 100,000 acres was chosen because it is a round number and the amount of cottonized flax produced from this area would be well below the projected quantities that would be demanded at the high cottonized flax target cost price of US$1,330 (i.e., C$1,900).

b/ Assume 100 kg/acre and 850kg/acre of clean tow respectively from oilseed and fiber flax. Assume that cottonized yield is 70% from oilseed flax tow and 80% from fiber flax tow.

c/ For oilseed flax assume $100/acre and for fiber flax $200/acre.

d/ Assume 100,000 or 62,500 tonnes of oilseed flax creates five jobs and every 1,000 tonnes of fiber cleaned and cottonized would created an additional three jobs.

Although one can argue about the accuracy of individual numbers in the table, one cannot argue with the general conclusions given by the numbers in the table and that is that:

> **In the long run, there are significant export, added value and job creation opportunities to be had by using newly developing technologies to produce and cottonize flax fiber within the province.**

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